TECHNICAL REPORT 072

Long-term Effects of Cattle and Wildlife Grazing on Grassland Plant Community Recovery in the East Kootenay Region of British Columbia

2012

BRITISH COLUMBIA

Long-term Effects of Cattle and Wildlife Grazing on Grassland Plant Community Recovery in the East Kootenay Region of British Columbia

B.M. Wikeem, T.J. Ross, and R.F. Newman

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Library and Archives Canada Cataloguing in Publication

Wikeem, Brian M

Long-term effects of cattle and wildlife grazing on grassland plant community recovery in the East Kootenay Region of British Columbia / B.M. Wikeem, T.I. Ross and R.E. Newman.

Available also on the Internet.
Includes bibliographical references.
ISBN 978-0-7726-6608-6

1. Grassland plants--Effect of grazing on--British Columbia--East Kootenay. 2. Grassland restoration--British Columbia--East Kootenay. 3. Grassland conservation--British Columbia--East Kootenay. I. Newman, Reg E. II. Ross, Timothy I. (Timothy James), 1956- III. British Columbia. IV. Title.

SB193.3.C36 W54 2012 333.7409711'65 C2012-980192-5

Electronic monograph in PDF format.
Issued also in printed form.
Includes bibliographical references.
ISBN 978-0-7726-6612-3

SB193.3.C36 W54 2012 333.7409711'65 C2012-980193-3

Citation

Wikeem, B.M., T.I. Ross, and R.E. Newman. 2012. Long-term effects of cattle and wildlife grazing on grassland plant community recovery in the East Kootenay Region of British Columbia. Prov. B.C., Victoria, B.C. Tech Rep 072. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr072.htm

Authors' affiliations

B.M. Wikeem
Natural Resource Management Consultant
SolTerra Resources Inc.
Bowser, B.C.

R.E. Newman
Ministry of Forests, Lands and Natural Resource Operations
Thompson Okanagan Region
Kamloops, B.C.

T.I. Ross
Ross Range and Reclamation Services
Cranbrook, B.C.

Copies of this report may be obtained from:
Crown Publications, Queen's Printer
PO Box 9452 Stn Prov Govt
Victoria, BC V8W 9V7
1-800-663-6105
www.crownpub.bc.ca

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ABSTRACT

In 1990, the East Kootenay Trench Agriculture Wildlife Committee was formed to mitigate long standing conflicts concerning forage allocation among cattle, elk, and deer in the Rocky Mountain Trench in southeastern British Columbia. A habitat monitoring program was initiated in 1991 at Skookumchuck Prairie, Premier Ridge, and Pickering Hills, and a report summarizing 4 years of results was completed in 1997. The original sites were re sampled in 2009 to evaluate 18 years of wildlife and cattle grazing. An un gulate exclosure was constructed at the Skookumchuck Prairie Historical Exclosure Site in 1951 and was sampled at about 10 year intervals between 1960 and 2009. In 1951, plant communities on both the grazed and ungrazed areas were dominated by early seral species. Over the 60 years of protection inside the exclosure, the plant community advanced to a stand dominated by rough fescue (*Festuca scabrella*) and Idaho fescue (*Festuca idahoensis*), whereas the plant community on the grazed area remained at an early seral stage. Bluebunch wheatgrass (*Agropyron spicatum*), which was virtually ab sent inside the exclosure in 1951, peaked in cover by 1970 and then declined from about 50% cover to less than 5% by 2009. Constructed in 1991, the Skoo kumchuck Prairie "Three way Exclosure" Site was divided into three grazing treatment areas to allow differential access to cattle, wildlife, and cattle and wildlife together. An exclosure was also constructed adjacent to the grazed areas to prevent all ungulate grazing. Early seral plant communities dom inated all four areas in 1991, and little change was apparent in any of the treatment areas until the site was re sampled in 2003. After 18 years, rough fescue and Idaho fescue cover had increased significantly in the Ungulate Ex closure and Cattle Only Area, but cover of these species remained negligible on the Wildlife Only and Combined Use Areas. Vegetation changes in both the grazed areas and ungrazed exclosures at Premier Ridge and Pickering Hills were essentially stagnant for 18 years, indicating that historical grazing by cattle and wildlife had impeded recovery. Widely dispersed rough fescue plants were found on both sites, indicating that ecological potential for recov ery exists. The exclosures at the Skookumchuck Prairie Historical Exclosure Site, and the Ungulate Exclosure and Cattle Only Area at the Three way Ex closure Site, demonstrate that these rangelands can recover to higher seral stages given proper management and sufficient time. Plant communities re sulting from such recovery, however, will contain a mix of native dominant species and naturalized alien species that may have reached a new "steady state" or "potential natural community." While improved livestock and wild life management is essential for recovery and long term sustainability of range resources, external management inputs, such as fire, chemical treat ments, or mechanical treatments, may be necessary to achieve desired plant communities. Long term exclosures provide a rare opportunity to evaluate undisturbed plant communities over extended time periods. Such informa tion affords insight into possible end points in succession, which are valuable for assessing the effects of grazing management and other disturbance re gimes. The rate of recovery provides us with a framework for management to gauge reasonable time frames for plant community change and evaluate the composition and productivity of various seral stages to supply resource val ues.

ACKNOWLEDGEMENTS

The authors wish to thank the following people for their contributions to this project:

- Brian Behr – Agricultural Research and Development Corporation
- Leanne Colombo – British Columbia Ministry of Forests, Lands and Natural Resource Operations
- Wendy Larsen – Kootenay Livestock Association
- Ray Morello – British Columbia Ministry of Forests, Lands and Natural Resource Operations
- Dan Murphy – Rocky Mountain Trench Natural Resources Society
- Darrell Smith – British Columbia Ministry of Agriculture
- Wayne Stetski – Formerly with British Columbia Ministry of Environment
- Jordy Thibeault – Kootenay Livestock Association

Funding was provided by:

- Agricultural Research and Development Corporation through the Agri culture Environment Fund
- British Columbia Cattlemen's Association through the Horn Levy Fund
- Rocky Mountain Trench Ecosystem Restoration Program

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Rocky Mountain elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and cattle (*Bos taurus*) have shared grassland and open forest range in the East Kootenay Region of southeastern British Columbia for more than 150 years. Early explorers and settlers, however, found the landscape dominated by forest with few large ungulate species present (Spry 1968; Nisbet 1994). A large part of the contemporary open range in the Rocky Mountain Trench (the Trench) portion of the region resulted from fires in the low-elevation forests during the 1920s and 1930s, which provided ideal habitat and range for wild ungulates and domestic livestock (Paish and Associates 1970). Since the last major forest fires in 1931, forest encroachment has advanced into these open areas, reducing forage capability for both wildlife and cattle (Paish and Associates 1970).

In the mid-1950s, a number of wildlife, soil, and range surveys were conducted to determine the status of ungulate populations, habitat, and range resources in the East Kootenay Region (Sugden 1953; Ashford et al. 1956; Kelley and Sprout 1956). Collectively, these assessments concluded that grasslands were overgrazed and the carrying capacity for wildlife and livestock was being exceeded. The following issues were identified as significant problems:

- livestock were being turned out before range readiness;
- ranges were overstocked with livestock;
- bunchgrasses were being overused;
- bluebunch wheatgrass (*Agropyron spicatum*)[1] and rough fescue (*Festuca scabrella*) were becoming scarce on the open range compared to areas protected from grazing;
- livestock were reluctant to graze forest range and areas distant from water;
- overuse was particularly high near water; and
- weedy species were invading grassland range.

Conflicts emerged during the 1960s and 1970s concerning dietary overlap and forage allocation among cattle, elk, and deer. While most of the debate focussed on large ungulate grazing, other factors, such as fire, fire suppression, forest ingrowth and encroachment, logging, land alienation, and recreation, also contributed to declining range and wildlife habitat resources in the area (Pitt 1982). Three interacting factors, however, have dominated resource management in the East Kootenay since the 1960s: potential competition between native ungulates and domestic livestock, forest ingrowth and encroachment, and deterioration of range condition (Pitt 1982).

Co-ordinated Resource Management Planning was introduced into the East Kootenay Region in 1975 primarily to resolve forage allocation conflicts between cattle and elk, and to ensure the long-term sustainability of the range resource. Although most resource managers believed that forage availability had improved with co-ordinated planning, many still contended that grazing pressure, forest ingrowth, and land alienation were resulting in declining range condition, and that an equitable forage allocation process was necessary to mitigate conflicts (Pitt 1982).

1 Vascular plant nomenclature follows Hitchcock and Cronquist 1973.

The East Kootenay Trench Agriculture Wildlife Committee (EKTAW) was formed in 1990 to alleviate long-standing wildlife–livestock conflicts on Crown and private land in the East Kootenay Trench (Gayton and Hansen 1997). In 1991, the committee initiated its Vegetation Monitoring Program to obtain local information on various issues related to the conflict. It aimed to:

- promote stewardship of the range resource;
- maintain and enhance compatible use of forest and rangeland for grazing;
- encourage management practices that optimize distribution of livestock and wildlife on common range; and
- sustain biodiversity of rangeland and wildlife habitat.

Between 1991 and 1994, data were collected on three important winter ranges in the Trench to evaluate operational grazing by cattle, deer, and elk, and to study the effects of grazing by cattle, wildlife, and cattle and wildlife together, under controlled conditions. A report summarizing the results was completed in 1997 (Ross 1997). Additional data collected in 2003 demonstrated that changes were occurring among the areas grazed by cattle only, wildlife only, cattle and wildlife together, and within an area that excluded all ungulate grazing (Rosentreter 2006).

In this project, vegetation plots were re-sampled at all sites that were established in 1991 by the EKTAW Vegetation Monitoring Program to determine the implications of 18 years of wildlife and cattle grazing on the sites. The specific objectives of the project were to:

- evaluate plant community response over time in grazed and ungrazed areas at each site with emphasis on key species of ecological and management importance in the region; and
- determine the differential effects of wild ungulate versus cattle grazing on these sites.

2 DESCRIPTION OF STUDY AREAS

The study was conducted on three important winter ranges for elk and deer in the Rocky Mountain Trench within 60 km of Cranbrook, BC. Two sites, called the Skookumchuck Prairie Historical Exclosure Site and the Skookumchuck Three-way Exclosure Site, are located at Skookumchuck Prairie; the other two sites are situated at Pickering Hills and Premier Ridge (Figure 1). Each location is rotationally grazed by cattle and represents a significant area of conflict in the Trench.

2.1 Landforms and Soils

Skookumchuck Prairie occurs on flat river terrace deposits along the Kootenay River, while Pickering Hills and Premier Ridge occupy morainal soils above the floodplain. Topography at Skookumchuck Prairie is mostly flat. Both Premier Ridge and Pickering Hills are located on steep, undulating, south- and southwest-facing slopes.

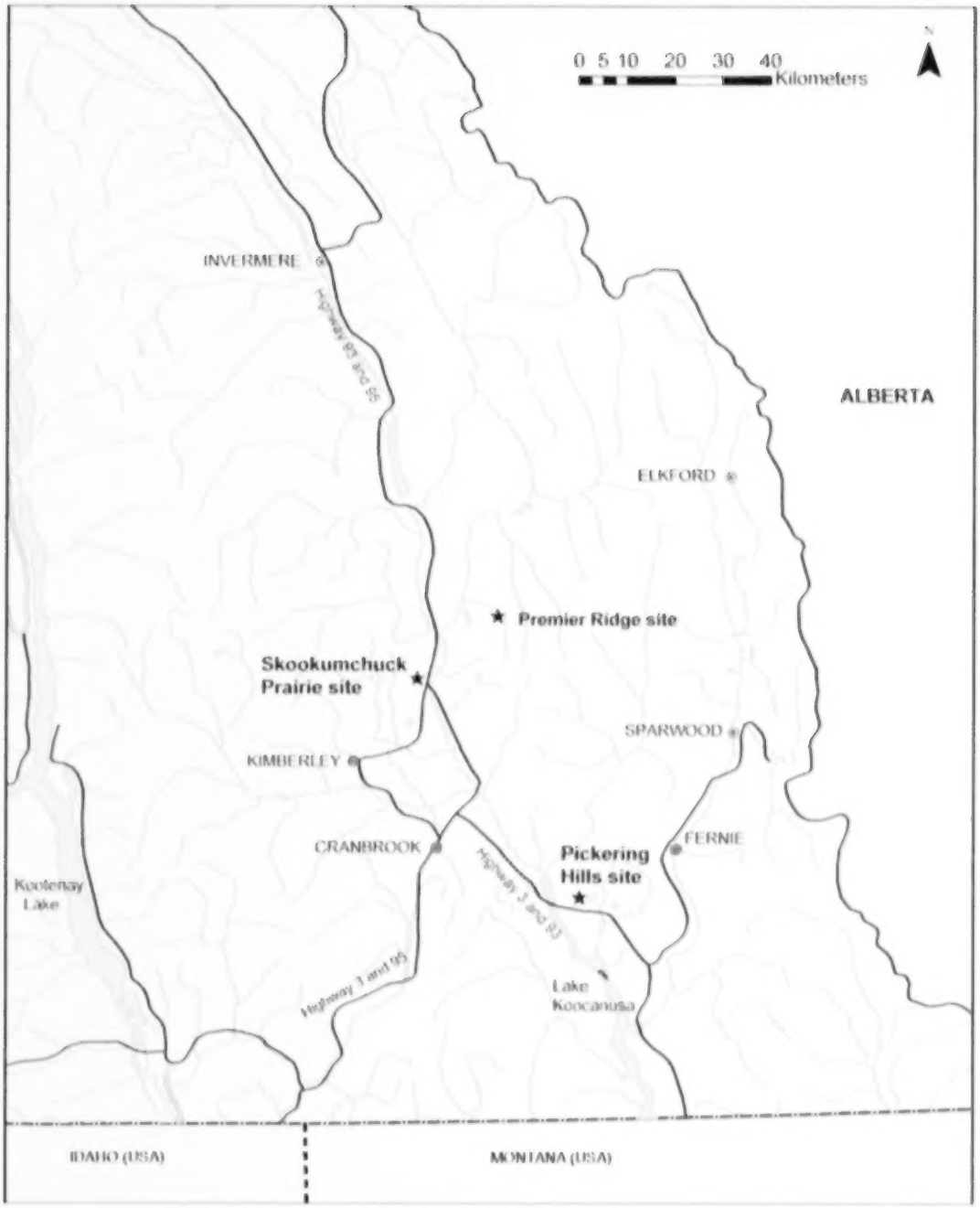

FIGURE 1. *Location of study sites in the East Kootenay Region of British Columbia.*

Nearly all soils in the Rocky Mountain Trench were derived from glacial deposits (Kelley and Sprout 1956; Lacelle 1990). Soils at all three locations are classified as Orthic Eutric Brunisols and range from 70 to 90 cm in depth. In a typical terrace soil, the upper part of the solum consists of gravelly or fine sandy loam, while the lower profile is comprised of a matrix of stratified me

dium gravel and scattered stones (Kelley and Sprout 1956). The texture in morainal soils ranges between silt loam and gravelly silt loam. Coarse fragments vary between 20 and 60% and consist of subangular and subrounded gravels, cobbles, and stones (Lacelle 1990).

2.2 Climate

The climate in the Rocky Mountain Trench is variable depending on elevation: upland areas receive slightly more precipitation and have cooler temperatures than the floodplain. Kelley and Sprout (1956) characterized the climate near Cranbrook as semi-arid with weather patterns influenced by cold continental air masses from the north in winter and heated air masses from the southern United States in summer.

Normal precipitation from 1990 to 2009 at the Cranbrook Airport, which is approximately centrally located among the three study locations, averaged slightly more than 37 cm annually (Table 1). Precipitation is bi-modally distributed, with peaks in November–January (mostly snow) and May–June (rain). Maximum precipitation falls in June, and October is generally the driest month (Table 1).

Temperature varies throughout the year, with the warmest readings occurring in July (25.6°C) and August (25.4°C) and the coldest occurring in December (−11.8°C) and January (−8.4°C). The absolute extremes on record are a high of 36.6°C in July 1985 and a low of −40.0°C in December 1975. The Rocky Mountain Trench receives an average of 2205.3 hours of sunshine and approximately 110 frost-free days annually (Environment Canada 2010).

2.3 Vegetation

Skookumchuck Prairie is located in the Ponderosa Pine Kootenay Dry Hot (PPdh2) biogeoclimatic subzone variant (Braumandl and Curran 1992). The site is predominantly open grassland interspersed with groves of ponderosa pine (*Pinus ponderosa*) and trembling aspen (*Populus tremuloides*). Herbaceous vegetation consists of Kentucky bluegrass (*Poa pratensis*), Canada bluegrass (*Poa compressa*), Richardson's needlegrass (*Stipa richardsonii*), rough fescue, Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass, and a variety of forbs, while bitterbrush (*Purshia tridentata*) and saskatoon (*Amelanchier alnifolia*) are important browse species on the site (see Appendix 1 for a complete list of common and scientific names of plant species in this study).

Premier Ridge and Pickering Hills are located in the Interior Douglas-fir Kootenay Dry Mild (IDFdm2) biogeoclimatic subzone variant (Braumandl and Curran 1992). Vegetation consists of open grass/shrubland intermingled with mixed stands of Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine, and trembling aspen. Both sites are in an early seral stage dominated by Kentucky bluegrass and western needlegrass (*Stipa occidentalis*), although rough fescue and bluebunch wheatgrass occur very infrequently. Bitterbrush and saskatoon are the dominant shrubs on both sites.

2.4 Wildlife and Cattle

Co-ordinated Resource Management Planning resulted in improved forage availability, forage quality, and productivity for wild ungulates and domestic livestock in the East Kootenay Region (Pitt 1982). Between 1982 and 1986, the East Kootenay elk population increased from nearly 10 000 to more than 28 000 animals (Demarchi et al. 1987) and then declined to about 25 000 in 1991 (Simpson 1992). In 2001, however, wildlife managers concluded, in an elk management plan, that "Current habitat condition on all potential winter

TABLE 1 *Monthly precipitation (cm) and normals (%) at the Cranbrook Airport between 1990 and 2009*

	Year																				
Month	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	**Normal**
January	4.0	1.7	1.8	2.9	1.1	3.3	3.3	3.5	4.6	2.4	3.7	0.4	1.6	2.9	2.4	2.5	5.3	2.8	2.6	0.8	2.5
February	1.9	1.3	1.6	1.8	3.0	1.0	3.0	0.5	0.6	3.6	2.0	0.8	4.2	1.3	1.0	0.4	1.6	3.2	1.5	1.7	2.2
March	0.8	5.6	1.0	0.5	1.2	4.4	1.6	3.5	4.2	0.9	3.3	2.0	1.7	2.8	1.1	2.4	1.5	2.1	1.3	4.9	2.1
April	2.3	2.8	2.8	1.5	4.0	3.5	3.6	2.5	0.9	1.9	1.9	3.3	2.6	3.8	2.3	0.6	4.4	1.0	1.1	2.5	2.8
May	11.8	3.3	3.5	3.6	4.8	3.5	7.5	6.4	10.6	4.4	1.9	1.3	12.8	3.7	3.6	4.9	2.3	6.7	3.4	1.9	4.6
June	6.3	2.8	5.9	12.7	6.9	13.0	4.6	3.3	7.8	5.9	2.2	4.9	3.3	3.4	4.3	19.0	5.6	6.1	3.6	5.2	5.1
July	3.2	4.3	7.7	10.2	0.5	6.8	3.2	1.4	4.0	5.6	2.3	3.7	3.4	0.4	4.4	1.5	4.5	1.8	3.0	5.4	3.4
August	2.5	1.6	0.9	4.3	1.3	4.1	0.7	1.8	0.9	2.8	1.1	0.5	1.1	1.5	6.8	6.3	2.2	1.0	2.9	6.4	2.9
September	0.0	2.9	1.9	4.5	0.3	2.5	2.7	2.3	3.2	0.2	2.7	1.6	4.4	4.9	6.4	6.5	3.7	1.2	1.8	1.3	3.1
October	3.6	0.6	2.4	1.1	4.4	2.4	3.8	2.0	1.1	2.5	0.5	1.1	0.3	1.9	3.0	2.8	5.0	1.3	1.7	6.0	1.8
November	5.4	4.0	3.5	2.6	2.3	4.5	8.9	0.3	4.8	5.6	1.6	2.1	1.0	3.2	1.3	3.8	9.7	2.5	1.5	1.3	3.6
December	3.7	1.1	3.0	3.1	3.2	6.8	9.3	0.7	3.4	1.5	3.1	3.8	5.4	2.4	2.9	2.3	3.6	5.9	5.0	1.7	3.0
Total	45.4	32.0	36.0	48.7	32.8	55.7	52.2	27.9	46.1	37.1	26.3	25.3	42.0	32.2	39.3	53.1	49.3	35.5	29.5	39.2	37.1
Normal																					
Annual	122.3	86.3	97.1	131.3	88.4	150.2	140.6	75.3	117.8	100.1	70.8	68.3	113.1	86.9	106.0	143.0	132.9	95.7	122.3	86.3	97.1
Growing season	29.7	18.3	25.2	37.8	22.0	35.7	26.1	19.5	28.6	23.2	12.7	16.3	28.0	19.5	30.7	41.6	27.6	19.1	17.5	28.7	23.7

range (gross suitability) is estimated to support 41 400 elk, while the net suitability (minus private land) has the potential to support 24 400 elk" (Bircher et al. 2001).

Livestock Animal Unit Months (AUMs) in the Trench peaked in 1964 (72 900 AUMs). By 1980, they were down to 44 200 AUMs (Pitt 1982). AUMs varied between 35 000 and 45 000 between 1980 and 2006 (British Columbia Ministry of Forests and Range, unpubl. data).

3 METHODS

3.1 Fence Construction and Layout

Exclosures were constructed at four sites in 1991 to provide "grazed" and "ungrazed" areas for sampling (Table 2). The exclosures at Skookumchuck Prairie Historical Exclosure Site, Premier Ridge, and Pickering Hills measured approximately 70 × 70 m, while the exclosure at the Skookumchuck Prairie Three-way Exclosure Site was 100 × 70 m. All the exclosures were constructed with 2.8-m page wire fencing to exclude all ungulate grazing.

TABLE 2 *Characteristics of sites used to examine the effect of grazing treatments over time on key plant species*

Site	Years sampled	Exclosure size (ha)	BEC unit[a]	Elevation (m)
Skookumchuck Prairie Historical Exclosure Site — Original exclosure	1960, 1970, 1982, 1991, 1994, 2009	0.5	PPdh2	800
Skookumchuck Prairie Historical Exclosure Site — New exclosure	1991, 1994, 2009	0.5	PPdh2	800
Skookumchuck Three-way ungulate exclosure	1991, 1994, 2003, 2009	0.7	PPdh2	810
Pickering Hills exclosure	1991, 1994, 2009	0.5	IDFdm2	1025
Premier Ridge exclosure	1991, 1994, 2009	0.5	IDFdm2	1035

a BEC: Biogeoclimatic Ecosystem Classification; PPdh2: Ponderosa Pine Kootenay dry, hot; IDFdm2: Interior Douglas-fir Kootenay dry, mild.

The Skookumchuck Three-way Exclosure was divided into three compartments to allow differential access to cattle, wildlife, and cattle and wildlife together. A fourth compartment (Ungulate Exclosure) was constructed to prevent all ungulate grazing, which acted as an ungrazed control. The Cattle Only Area (65 ha) was fenced with 2.8-m page wire fencing and serves as an enclosure for cattle while excluding native ungulate grazing. The Wildlife Only Area (65 ha) was fenced with 1.2-m barbed wire to exclude cattle while permitting deer and elk access. This site is located immediately south of the Cattle Only Area. An unfenced area of approximately 65 ha (Combined Use Area) was defined east of the fenced areas to assess joint use by cattle and wildlife. The Ungulate Exclosure, which measures 100 × 70 m, is located adjacent to the Cattle Only Area and was also constructed with 2.8-m page wire fencing (Table 2).

3.2 Livestock and Wildlife Grazing

The Skookumchuck Prairie Historical Exclosure Site and the Skookumchuck Three-way Exclosure are located in the TaTa/Skookumchuck Range Unit in

Plot and Pulp pastures, respectively. The Premier Ridge Site is located in Sheep Pasture in the Wolf/Sheep Range Unit, while the Pickering Hills Site is located in Pickering Hills Pasture in the Pickering Hills Range Unit.

Cattle grazing at Skookumchuck Three-way Exclosure, Pickering Hills, and Premier Ridge followed the operational prescriptions set by the British Columbia Ministry of Forests and Range. Generally, each pasture was grazed for approximately 1 month annually on a spring/fall rotation, although the AUMs used and season of use varied during the study (Table 3; Appendix 2).

Wild ungulates followed normal distribution patterns in all parts of the pastures they had access to during the study, but the exact number of deer and elk using each pasture was not documented. Throughout the study period, elk surveys were conducted at several polygons within the management units where the sites are located, and population estimates were calculated for the management unit as a whole (Table 4). Similarly, other data collected between 1991 and 1993 indicated that overwintering elk spent between 185 and 222 days at Skookumchuck Prairie, between 171 and 183 days at Premier Ridge, and slightly more than 160 days at Pickering Hills during those years (Jamieson and Hebert 1993).

TABLE 3 *Cattle stocking and rotations at Skookumchuck Prairie, Premier Ridge, and Pickering Hills between 1992 and 2009*

Site	Pasture[a]	Area (ha)	AUMs[b]	Stocking rate (ha/AUM)	Spring[c]	Fall[d]	Rest[e]	No data	Total
Skookumchuck Prairie Historical	Plot	675	87–194	7.8–3.5	7	1	4	6	18
Skookumchuck Three-way Exclosure – Cattle Only Area	Pulp	65	27–71	2.4–0.9	10	2	3	3	18
Skookumchuck Three-way Exclosure – Combined Use Area	Pulp	320	38–255	8.4–1.3	9	4	3	2	18
Pickering Hills	Pickering Hills	292	114–320	2.6–0.9	0	17	1	0	18
Premier Ridge	Sheep	231	50–107	4.6–2.2	3	8	4	3	18

a Pasture – British Columbia Ministry of Forests, Lands and Natural Resource Operations pasture name.
b AUMs – Range in Animal Unit Months over the study period.
c Spring – Number of years with spring grazing over the study period.
d Fall – Number of years with fall grazing over the study period.
e Rest – Number of years where pasture rested over the study period.

TABLE 4 *Elk population estimates from three management units in the Rocky Mountain Trench between 1992 and 2008*

Site	Management Unit	Numbers of elk[a]			
		1992	1997	2001	2008
Skookumchuck Prairie	MU 4-20	1000	850	1100	2526
Premier Ridge	MU 4-21	1500	1200	1600	1902
Pickering Hills	MU 4-22	2050	1900	2100	3417
Total East Kootenay		11 038	7762	10 733	14 115

a Sample sizes relative to the overall study area. Source: Phillips et al. 2008.

3.3 Assessment of Plant Cover

Plant species cover was assessed on all sites using a modification of the canopy coverage method (Daubenmire 1959) with nested plots. Cover of grasses, forbs, and soil substrates was estimated using a 20 × 50 cm (0.1 m^2) plot, which was nested in a 1 × 2 m plot used to determine tree and shrub cover.

Cover, or the vertical projection of the plant canopy to the ground, was estimated for each vascular species according to six cover classes (Daubenmire 1959). Cover of litter and exposed mineral soil was also recorded. Species not occurring in the plots but within a 3-m band on each side of the transect were recorded as trace.

At the Skookumchuck Three-way Exclosure, 10 plots were systematically located along each of ten 50-m transects in the Ungulate Exclosure, and in the Wildlife Only, Cattle Only, and Combined Use areas. At Premier Ridge and Pickering Hills, five 50-m transects, each with 10 plots, were sampled within exclosures and in the area grazed by elk, deer, and cattle. Five paired transects were also installed inside the Skookumchuck Prairie Historical New Exclosure. Only a single transect was located in the grazed area and in the Skookumchuck Prairie Historical Exclosure. Depending on annual weather conditions, all sites were sampled between late June and early August each year to standardize sampling between years with plant phenology.

Percent cover for each species, litter, and exposed mineral soil was determined by averaging the midpoints of cover estimates over all plots at each location.

3.4 Data Analysis

Differences in cover of plant species and soil substrates were determined on all sites, with particular focus placed on key species of ecological and managerial importance. These included bluebunch wheatgrass, rough fescue, Idaho fescue, needle-and-thread (*Stipa comata*), prairie junegrass (*Koeleria cristata*), ponderosa pine, saskatoon, and bitterbrush. Plant species that provided less than 2% cover were usually combined in group totals for grasses, forbs, and shrubs unless a statistical difference occurred that was of ecological or management value.

3.4.1 Trends in key plant species over time Changes in plant and soil substrate cover between 1991 and 2009 were determined at Pickering Hills, Premier Ridge, and the two exclosures at the Skookumchuck Prairie Historical Site by using paired t-tests (Zar 1984). Separate t-tests were also performed to test for differences between the grazed and ungrazed areas at each site.

3.4.2 Effects of cattle and wild ungulate grazing The effects of wild ungulate and cattle grazing were based on an unreplicated study at the Skookumchuck Three-way Exclosure Site, which has value because of its unique and long-term nature. Ten subplots were arranged along each of 10 transects for a total of 100 subplots per treatment area. Data were analyzed as a two-factor repeated measures analysis of variance (ANOVA) using the sampling variability among transects as experimental error (Dormaar and Willms 1998). The effect of the grazing treatments over time was determined using single degree-of-freedom polynomial contrasts. The SAS procedure PROC MIXED was used for all analyses (SAS Institute 1988).

The analysis focussed primarily on the interactions between the grazing treatments over time (Graze × Year) to determine trends in key plant species

and soil substrates, thereby mitigating the possible effects of minor differences among the treatment areas at the onset of the study. A non-significant interaction term indicated that the slopes of the response over time were the same among grazing treatments. A significant interaction term indicated that the slopes of the response were different and independent of the initial condition.

Cover data were transformed using the base-10 logarithm to correct for non-normal distributions that tended to be skewed toward zero, and for heteroscedasticity where the variance increases proportionally with the mean (Zar 1984). Results from analyses based on transformed data are reported at their original scale. Conclusions from this project apply to the specific sites sampled and should be extrapolated only cautiously to ecologically similar sites where professional judgement warrants.

4 RESULTS

Two exclosures at Skookumchuck Prairie were used to study the long-term effects of cattle and wildlife grazing on plant communities and the response of key plant species compared to ungrazed conditions. Both sites are located in the PPdh2 variant. One exclosure had been established for 58 years, while the other was constructed when the study began in 1991. Two additional exclosures were sampled on two IDFdm2 variant sites at Premier Ridge and Pickering Hills. All exclosures were sampled over the same 18-year period.

4.1 Skookumchuck Prairie Historical Site Original Exclosure

The original exclosure at this site was constructed by the British Columbia Ministry of Forests in 1951 and has been sampled intermittently since 1960 at about 10-year intervals (Figure 2). Sandberg's bluegrass (*Poa sandbergii*), low pussytoes (*Antennaria dimorpha*), prairie junegrass, and needle-and-thread were the most common species in both the grazed and ungrazed areas when the exclosure was constructed. According to McLean and Tisdale (1972), there appeared to be very little bluebunch wheatgrass and nearly no rough fescue on the site in 1951.

4.1.1 Trends in key species over time—ungrazed exclosure Between 1960 and 2009, the plant community inside the exclosure experienced shifts in dominance among six grass species (Table 5). In 1960, bluebunch wheatgrass and prairie junegrass dominated the plant community in approximately equal proportions, with Sandberg's bluegrass and needle-and-thread providing slightly less cover. Low pussytoes was the main forb occupying the site, and trees and shrubs were absent (Table 5).

By 1970, bluebunch wheatgrass cover had peaked on the site and was the sole dominant species (Figure 3). Prairie junegrass, which had codominated with bluebunch wheatgrass, was replaced by rough fescue (Table 5). Over the next 39 years, however, bluebunch wheatgrass and prairie junegrass declined, and by 2009 they were almost absent on the site (Table 5).

Beginning in 1960, rough fescue steadily increased in the exclosure and was the dominant species in 1982, producing more than half of the total grass cover (Table 5). Beginning in 1991, rough fescue cover declined to approximately its 1970 cover, and from then until 2009, it remained the dominant

grass on the site (Table 5). Idaho fescue, which was absent on the site in 1960, first appeared inside the exclosure in 1982 (Table 5; Figure 3). Compared to bluebunch wheatgrass and rough fescue, Idaho fescue cover more than doubled inside the exclosure between 1991 and 2009 and codominated the site with rough fescue (Table 5; Figure 3).

Only minor changes in forb cover occurred inside the exclosure between 1960 and 2009, and most of the response resulted from changes in five species (Table 5). Overall forbs increased slightly between 1960 and 1970, with spiny phlox (*Phlox rigida*) and Nuttall's pussytoes (*Antennaria parviflora*) contributing most to the change. Low pussytoes, which was the dominant forb in 1960, had declined to less than 1% cover by 1982, while other forb species fluctuated over the next 39 years, likely in response to annual weather conditions (Table 5).

Litter cover, which was not sampled on the study area between 1960 and 1991, increased continuously in the ungrazed area between 1991 to 2009 (Figure 3). Cover of exposed mineral soil was very low in the ungrazed area in 1991 and remained at a low level until 2009 (Figure 3).

4.1.2 Trends in key species over time—grazed area Although the species composition on the grazed area was similar to that in the exclosure in 1951, the successional patterns and the response of individual species were different between the areas over the study period. In 1960, the grazed area was dominated by Sandberg's bluegrass and prairie junegrass, which jointly provided more than 40% canopy cover (Table 5). Needle-and-thread and bluebunch wheatgrass were also present, but collectively they accounted for only slightly more than 10% cover (Table 5).

By 1970, total grass cover had increased to more than 75% in the grazed area (Table 5). The principal grasses that increased included bluebunch wheatgrass, needle-and-thread, and prairie junegrass, whereas Sandberg's bluegrass declined. In 1970, needle-and-thread replaced prairie junegrass as the dominant species, and it remained the dominant grass from 1970 to 2009, although its cover varied among years (Table 5; Figure 3). Similar to the exclosure site, bluebunch wheatgrass cover increased between 1960 and 1970, and then declined gradually and finally disappeared on the grazed area by 2009 (Table 5; Figure 3).

Although rough fescue and Idaho fescue were both found in low to trace amounts on the grazed area, these species never increased in cover during the study period. Along with the trend in needle-and-thread, these responses represent the key differences in the development of the plant community on the ungrazed versus grazed areas (Figure 3).

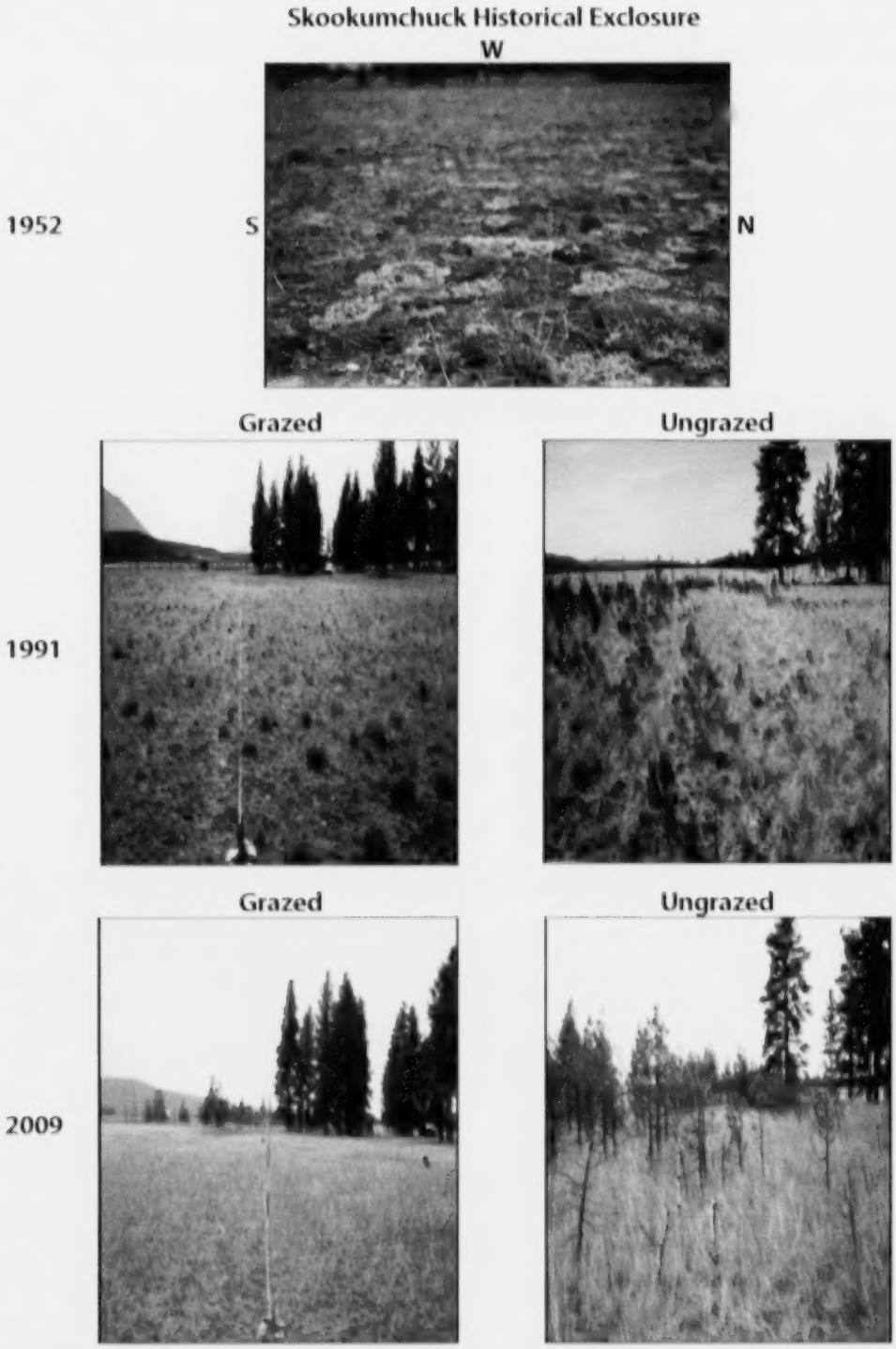

FIGURE 2 *Vegetation development between 1952 and 2009 at Skookumchuck Prairie Historical Exclosure Site near Skookumchuck, B.C.*

TABLE 5 *Percent cover*

	Grazed						Exclosure					
Species[a]	1960	1970	1982	1991	1994	2009	1960	1970	1982	1991	1994	2009
Grasses												
Bluebunch wheatgrass	6.8	13.0	14.0	7.6	6.4	0.0	24.7	55.0	12.7	5.4	8.1	2.2
Idaho fescue	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	1.0	7.9	25.0	18.5
Needle-and-thread	4.2	34.0	47.0	13.9	25.8	18.3	16.7	1.0	0.0	0.0	0.0	0.0
Prairie junegrass	16.6	20.0	5.0	0.9	14.0	1.0	23.4	9.0	4.2	1.0	4.7	0.0
Rough fescue	0.0	T[b]	T	0.9	1.0	0.0	6.0	20.0	58.8	23.8	32.3	23.5
Sandberg's bluegrass	26.2	10.0	0.0	0.4	0.1	0.1	17.5	5.0	0.1	0.3	0.1	0.0
Total Grass Cover	**53.8**	**77.0**	**66.0**	**24.4**	**48.3**	**20.8**	**88.3**	**90.0**	**76.8**	**38.4**	**70.2**	**44.2**
Forbs												
Low pussytoes	26.4	8.0	T	0.6	0.8	0.0	10.5	T	T	0.0	0.6	0.0
Nuttall's pussytoes	1.3	9.0	0.0	0.0	0.0	0.0	0.0	6.0	7.6	2.6	0.0	0.0
Prairie groundsel	0.0	0.0	2.0	1.9	6.9	0.0	0.0	0.0	3.4	1.1	2.5	0.0
Rosy pussytoes	0.0	0.0	4.0	3.0	4.6	6.0	0	0	0.0	0.0	8.3	4.3
Spiny phlox	1.1	3.0	2.0	3.1	6.7	0.7	0.0	11.0	10.5	4.8	7.6	2.9
Total Forb Cover	**34.7**	**27.0**	**16.0**	**12.4**	**30.3**	**22.2**	**13.3**	**18.0**	**27.2**	**10.4**	**31.9**	**11.8**
Trees												
Ponderosa pine	0.0	0.0	T	0.1	0.9	0.0	0.0	0.0	0.0	2.5	12.9	11.2
Total Tree Cover	**0.0**	**0.0**	**T**	**0.1**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**	**2.5**	**12.9**	**11.2**

a See Appendix 1 for scientific names of plant species that occur in tables but not in the text.
b T = Trace: denotes that the species was present on the site but was not sampled on the plots.

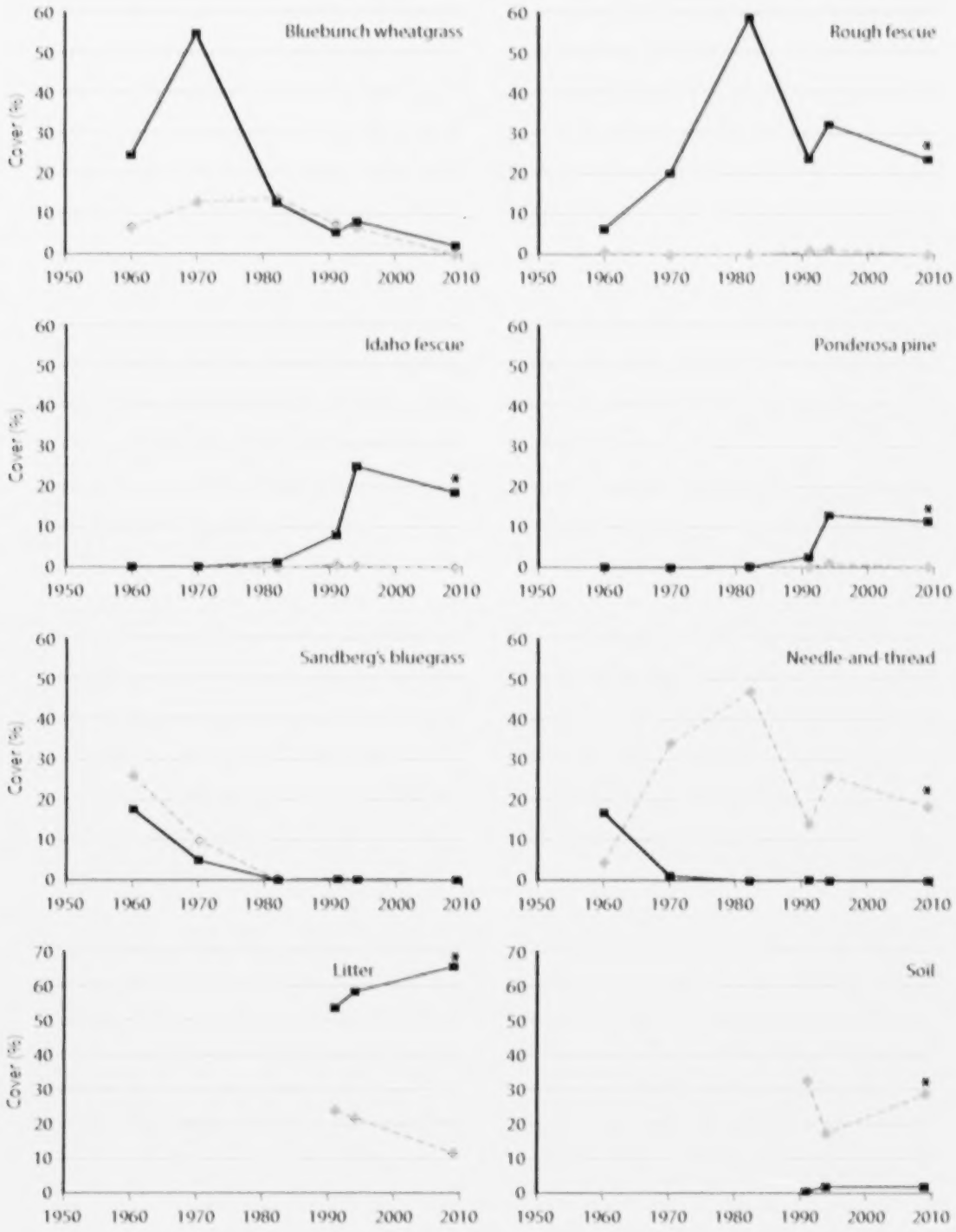

FIGURE 3 *Cover of key plant species and soil substrates at Skookumchuck Prairie Historical Exclosure Site between 1960 and 2009 for grazed (dashed line) and ungrazed (solid line) areas. Symbols (*) indicate a significant difference ($P<0.05$) between grazed and ungrazed areas within that year.*

Similar to the exclosure, the primary response of forbs as a group on the grazed area was attributed to changes in a few species (Table 5). In 1960, low pussytoes alone produced more than 75% of total forb cover (Table 5), but this species declined markedly by 1970 and comprised only a minor part of the flora for the rest of the study period. Other than spiny phlox, other forb species contributed little cover in the plant community and displayed some what erratic fluctuations in cover (Table 5).

Trees and shrubs were poorly represented on the grazed area. Except for ponderosa pine, which appeared between 1982 and 1994, no other trees or shrubs established on the grazed area over the 58 years of study (Table 5; Figure 3).

Unlike inside the exclosure, litter cover declined continuously in the grazed area between 1991 and 2009, while cover of exposed mineral soil in creased (Figure 3), reflecting the combined effects of grazing and disturbance by cattle and wild ungulates.

4.2 Skookumchuck Prairie Historical Exclosure Site New Exclosure

The new exclosure at the Skookumchuck Prairie Historical Site was built in 1991 as an attachment to the original exclosure. This site was first sampled in 1991 and was re sampled in 1994 and 2009.

Bluebunch wheatgrass and needle and thread dominated the site in 1991 with a combined cover exceeding 35% (Table 6). Prairie junegrass, rough fes cue, and Idaho fescue also occurred on the site as subordinates, collectively accounting for less than 10% of total grass cover (Table 6). Fifteen forb spe cies were present in 1991, but none of the species surpassed 2% cover. No trees or shrubs were recorded on the site.

After 18 years of ungulate exclusion, bluebunch wheatgrass, needle and thread, and Sandberg's bluegrass all declined significantly ($P<0.05$), while rough fescue, prairie junegrass, and Canada bluegrass all increased ($P<0.05$) (Table 6).

By 2009, forb cover nearly tripled compared to 1991, with cinquefoil spe cies (*Potentilla* spp.), rosy pussytoes (*Antennaria microphylla*), and western yarrow (*Achillea millefolium*) all becoming more prominent ($P<0.05$) on the site (Table 6). Trees or shrubs were still absent in 2009.

In 2009, cover of bluebunch wheatgrass, prairie junegrass, and rough fes cue were all higher ($P<0.05$) inside the new exclosure than on the grazed area adjacent to the original exclosure (Figure 4), but trends varied among spe cies. For example, bluebunch wheatgrass and prairie junegrass declined in both the exclosure and on the grazed area, whereas rough fescue increased

inside the exclosure only. In contrast, needle and thread declined slightly inside the exclosure and increased marginally on the grazed area (Figure 4).

Litter cover declined on both the ungrazed and grazed areas between 1994 and 2009, although it remained 8% higher ($P<0.05$) inside the exclosure. Cover of exposed mineral soil declined by 22% inside the exclosure ($P<0.05$) between 1991 and 2009. On the grazed area, however, it declined between 1991 and 1994 before increasing back to its original cover in 2009 (Figure 4).

TABLE 6 *Percent cover of key plant species and soil substrates at Skookumchuck Prairie Historical Exclosure Site New Exclosure between 1991 and 2009*

Species	1991	2009	Signif. P>F [a]
Grasses			
Bluebunch wheatgrass	20.3	9.9	*
Canada bluegrass	0.3	2.6	*
Idaho fescue	1.6	0.6	
Needle and thread	15.5	9.4	*
Prairie junegrass	3.8	6.8	**
Rough fescue	1.0	8.3	*
Sandberg's bluegrass	0.7	0.0	*
Forbs			
Cinquefoil species	0.1	4.8	*
Rosy pussytoes	1.0	4.3	*
Western yarrow	0.0	1.9	*
Trees and Shrubs			
Ponderosa pine	0.0	0.0	
Substrates			
Litter	35.9	19.7	*
Soil	30.5	6.7	*

a Asterisks indicate significance at * $P<0.05$ and ** $P<0.10$.

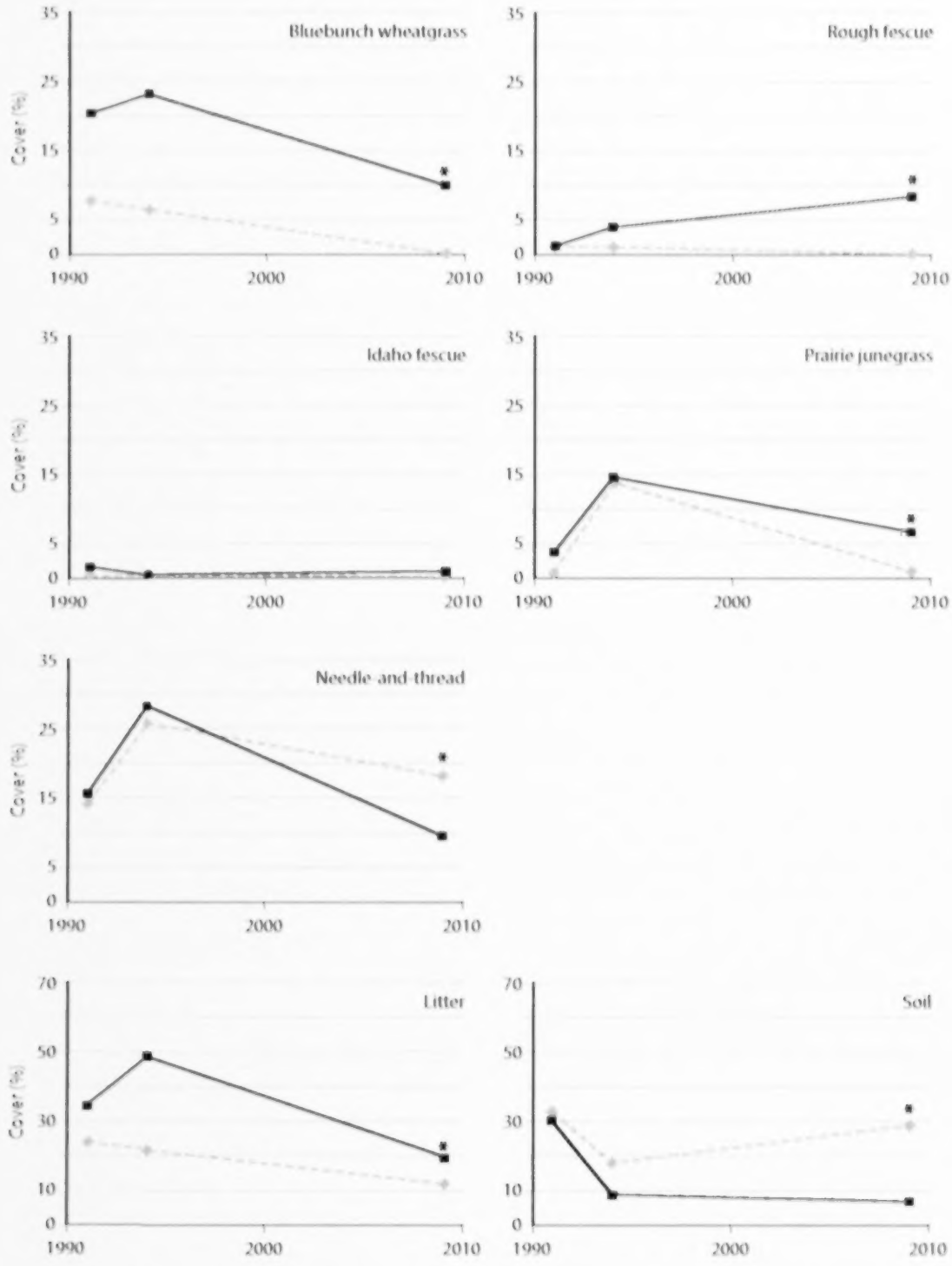

FIGURE 4 *Cover of key plant species and substrates at the new exclosure at Skookumchuck Prairie Historical Exclosure Site between 1991 and 2009 for grazed (dashed line) and ungrazed (solid line) areas. Symbols (*) indicate a significant difference ($P<0.05$) between grazed and ungrazed areas within that year.*

4.3 Premier Ridge

Exclosure — Kentucky bluegrass and western needlegrass were the dominant herbaceous species inside the exclosure in both 1991 and 2009 (Table 7; Figure 5) but Kentucky bluegrass cover remained constant between years (Table 7).

Western needlegrass and Columbia needlegrass increased inside the exclosure and collectively contributed about 10% to grass cover in 1991 and more than 20% in 2009 (Table 7). By comparison, Canada bluegrass cover declined ($P<0.05$) from slightly more than 3% in 1991 to no cover in 2009 (Table 7). Bluebunch wheatgrass, Idaho fescue, and rough fescue were not recorded in the exclosure in 2009.

A total of 25 forb species was found inside the exclosure during the study, but the number declined from 20 in 1991 to 13 in 2009. Total forb cover was relatively constant between years at 12% despite fewer species being present in 2009 (Table 7). Except for stoneseed (*Lithospermum ruderale*), all other forb species contributed less than 2% cover between 1991 and 2009 (Table 7).

Bitterbrush and saskatoon were the dominant shrubs inside the exclosure. Bitterbrush cover declined ($P<0.05$) between 1991 and 2009, whereas saskatoon cover remained relatively unchanged over the study period (Table 7; Figure 5). Soil substrate cover was not significantly different between years for either litter or exposed mineral soil (Table 7).

Grazed Area — Although nine grass species occupied the grazed area in 1991, Kentucky bluegrass and western needlegrass provided most of the canopy cover. Kentucky bluegrass dominated the grazed area in both years and doubled in cover ($P<0.05$) between 1991 and 2009 (Table 7). Western needlegrass was the subdominant species in 1991, but it declined ($P<0.05$) to 3% cover in 2009 (Table 7). Rough fescue and Idaho fescue did not occur on transects in either year, and only a few scattered Idaho fescue plants were found on the site in 2009 (Wikeem and Ross, pers. obs., 2009).

Collectively, 23 forb species were identified at Premier Ridge in 1991, but only 16 species were encountered in 2009. Spreading dogbane (*Apocynum androsaemifolium*) was the only species that contributed 2% or more to cover at any time (Table 7).

Shrub cover remained relatively constant between 1991 and 2009 at about 30% with bitterbrush the dominant shrub in both years in the grazed area (Table 7). Litter cover increased ($P<0.05$) in the grazed area between 1991 and 2009, but cover of exposed mineral soil remained unchanged between years (Table 7).

TABLE 7 *Percent cover of key plant species and soil substrates at Premier Ridge between 1991 and 2009*

Species	Grazed			Exclosure		
Grasses	**1991**	**2009**	**Signif. *P>F*[a]**	**1991**	**2009**	**Signif. *P>F*[a]**
Bluebunch wheatgrass	0.9	3.6		0.0	0.0	
Canada bluegrass	2.0	1.9		3.1	0.0	*
Cheatgrass	0.9	0.3		0.0	0.0	
Columbia needlegrass	0.0	1.5	*	0.1	5.2	*
Idaho fescue	0.0	0.0		0.0	0.0	
Kentucky bluegrass	15.9	32.3	*	17.2	15.1	
Prairie junegrass	1.6	3.4		2.1	2.1	
Rough fescue	0.0	0.0		0.0	0.0	
Western needlegrass	7.7	3.0	*	9.8	15.1	**
Total Grass Cover	**29.2**	**45.8**		**33.3**	**39.4**	
Forbs						
Spreading dogbane	2.0	3.5		1.6	1.9	
Stoneseed	0.8	1.7		0.4	2.0	**
Total Forb Cover	**7.8**	**12.5**		**11.8**	**12.6**	
Shrubs						
Bitterbrush	22.2	19.0		22.1	3.9	*
Saskatoon	1.9	0.9	*	1.0	5.6	
Total Shrub Cover	**31.9**	**28.4**		**34.0**	**22.6**	
Substrates						
Litter	42.0	56.7	*	37.8	46.9	
Soil	12.6	9.7		23.0	25.4	

a Asterisks indicate significance at * $P<0.05$ and ** $P<0.10$.

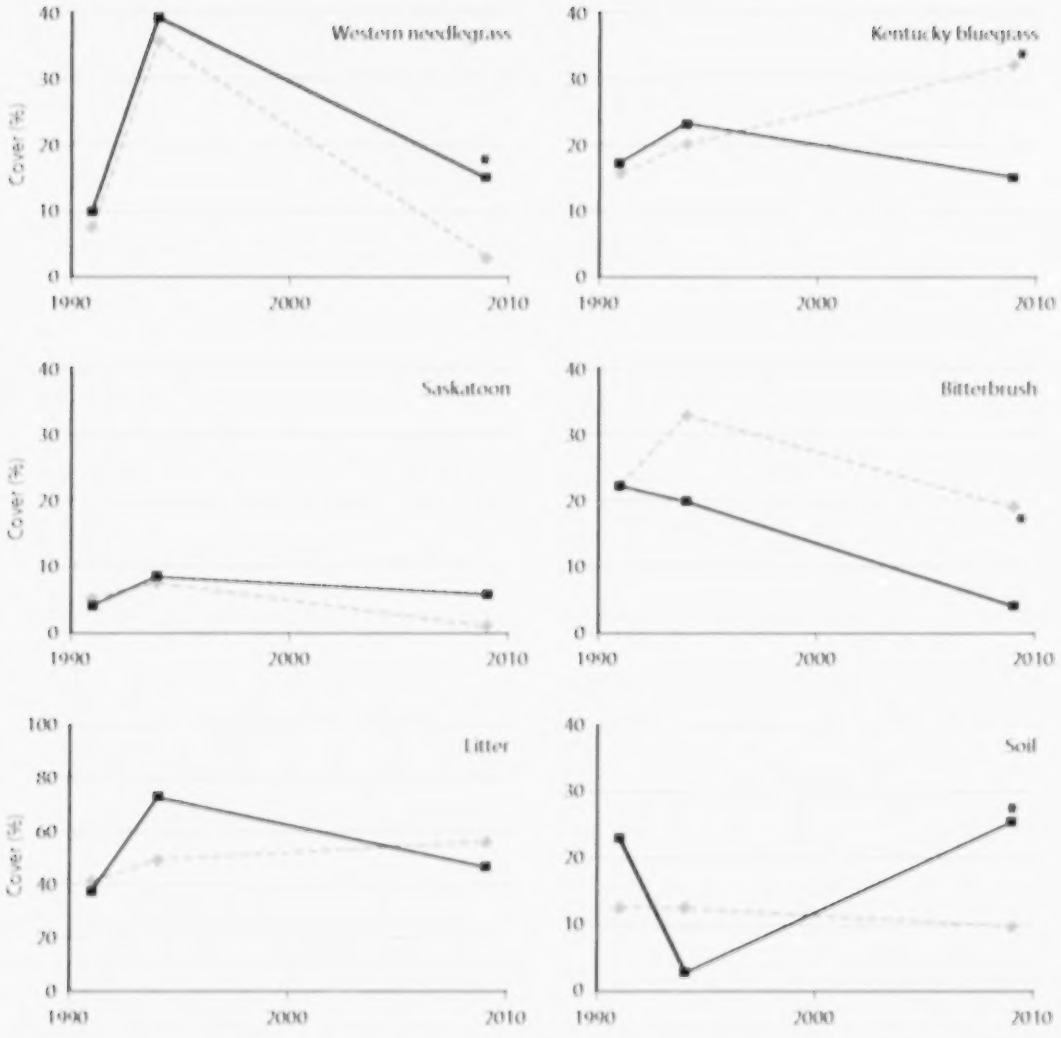

FIGURE 5 *Cover of key plant species and soil substrates at the Premier Ridge site between 1991 and 2009 for grazed (dashed line) and ungrazed (solid line) areas. Symbols (*) indicate a significant difference ($P<0.05$) between grazed and ungrazed areas within that year.*

Exclosure—Vegetation inside the exclosure was sparse in 1991, and vegetative cover was approximately equally distributed among grasses, forbs, and shrubs as groups (Table 8). Kentucky bluegrass and western needlegrass were the dominant grasses with a combined cover of about 30% (Table 8). Canada bluegrass, prairie junegrass, and cheatgrass (*Bromus tectorum*) were also present as minor species, while bluebunch wheatgrass, Columbia needlegrass (*Stipa columbiana*), Idaho fescue, and rough fescue were not present in 1991. By 2009, both Kentucky bluegrass and western needlegrass had declined ($P<0.05$) by more than 40%, whereas bluebunch wheatgrass, rough fescue, and Columbia needlegrass had established as minor species (Table 8).

Overall, total forb cover declined nearly 50% between 1991 and 2009, with chickweed (*Cerastium arvense*) accounting for most of the change ($P<0.05$). In contrast, spreading dogbane nearly quadrupled ($P<0.05$) during the period (Table 8), while other native forbs varied annually with minor changes in cover.

Total shrub cover in the exclosure doubled between 1991 and 2009 (Table 8). Bitterbrush was the dominant shrub, but its cover remained constant between 1991 and 2009 (Table 8). Saskatoon, buckbrush, and snowberry were also found inside the exclosure, but only saskatoon provided cover greater than 5% in 1991 (Table 8; Figure 6). By 2009, however, all three species had increased in the exclosure.

Exposed mineral soil cover declined ($P<0.05$) between 1991 and 2009, while litter cover quadrupled ($P<0.05$) during the same period (Figure 6).

Grazed Area—Total grass cover on the grazed area decreased in 2009 compared to 1991, but most of the changes for individual species were minor. Bluebunch wheatgrass and Idaho fescue, which were not found in the area in 1991, increased ($P<0.05$) slightly, while cheatgrass and Columbia needlegrass both declined ($P<0.05$; Table 8). By 2009, there were no changes in perennial bunchgrass cover in the grazed area compared to the exclosure, but cover of both Canada bluegrass and Kentucky bluegrass was marginally higher ($P<0.05$; Figure 6).

Total forb cover varied over the 18 years, with chickweed and spreading dogbane as the most prevalent species (Table 8). Spreading dogbane increased significantly ($P<0.05$) in 2009 compared to 1991, but chickweed declined (Table 8). Sulphur cinquefoil, diffuse knapweed, and spotted knapweed were all found in the grazed area, but none were recorded on transects (Wikeem and Ross, pers. obs., 2009).

Total shrub cover declined in the grazed area between 1991 and 2009 (Table 8). Although saskatoon, buckbrush, and snowberry were all present on the site, most of the change in shrub cover was attributed to bitterbrush, which declined by nearly 50% ($P<0.05$) between 1991 and 2009 (Table 8). In 2009, there was no significant difference in bitterbrush cover inside and outside the exclosure, but buckbrush and snowberry were both more prevalent in the exclosure after 18 years of protection (Figure 6).

Litter cover more than doubled in the grazed area and quadrupled inside the exclosure between 1991 and 2009 (Table 8), but, by 2009, it was only slightly lower in the grazed area than inside the exclosure (Figure 6). Exposed mineral soil cover showed the reverse trend and declined inside the exclosure (Table 8), while there was no significant change ($P>0.05$) is soil cover in the grazed area after 18 years (Table 8; Figure 6).

TABLE 8 *Percent cover of key plant species and soil substrates at Pickering Hills between 1991 and 2009*

Species	Grazed			Exclosure		
Grasses	**1991**	**2009**	**Signif. $P>F$ [a]**	**1991**	**2009**	**Signif. $P>F$ [a]**
Bluebunch wheatgrass	0.0	2.0	*	0.0	0.1	*
Canada bluegrass	1.7	6.4		1.3	0.0	*
Cheatgrass	2.1	0.0	*	1.1	0.0	*
Columbia needlegrass	4.7	0.5	*	0.0	3.8	*
Idaho fescue	0.0	0.1	*	0.0	0.0	
Kentucky bluegrass	23.8	19.7		16.0	8.4	*
Prairie junegrass	1.9	1.3		0.8	0.1	
Rough fescue	0.0	0.0		0.0	2.0	
Western needlegrass	7.4	7.0		14.9	4.9	*
Total Grass Cover	**42.7**	**38.0**		**35.4**	**32.4**	
Forbs						
Chickweed	3.3	0.0	*	10.2	0.1	*
Spreading dogbane	2.2	8.3	*	1.2	4.6	*
Total Forb Cover	**18.6**	**22.9**		**19.3**	**10.1**	
Shrubs						
Bitterbrush	20.9	11.6	*	12.4	12.3	
Saskatoon	7.4	4.3		6.5	8.2	
Total Shrub Cover	**36.9**	**27.3**		**27.0**	**53.9**	
Substrates						
Litter	35.9	78.6	*	23.4	94.6	*
Soil	4.0	5.6		11.2	0.4	*

a Asterisks indicate significance at * $P<0.05$.

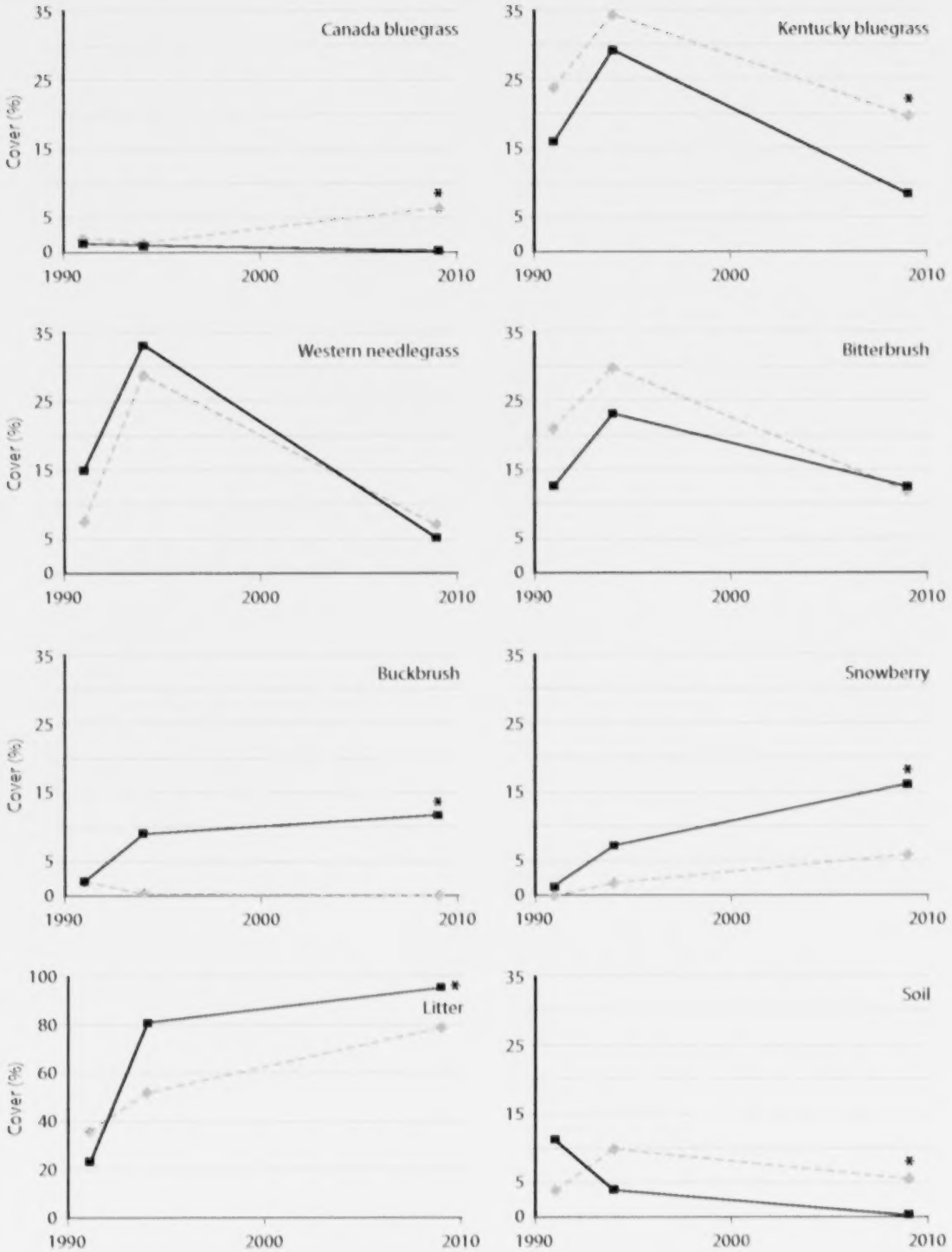

FIGURE 6 *Cover of key plant species and soil substrates at the Pickering Hills between 1991 and 2009 for grazed (dashed line) and ungrazed (solid line) areas. Symbols (*) indicate a significant difference ($P<0.05$) between grazed and ungrazed areas within that year.*

4.5 Skookumchuck Prairie Three-way Exclosure Site

Floristic changes among the four grazing treatment areas at the Skookumchuck Three-way Exclosure Site have been gradual and varied. After 18 years, differences in the plant communities are finally emerging, which are best expressed by the response of individual key species, species groups, and soil attributes.

4.5.1 Effects of cattle and wild ungulate grazing In 1991, the four grazing treatment areas were in a relatively early seral stage with similar floristic composition. Total grass cover averaged about 30% in each area (Table 9). Bluebunch wheatgrass was the dominant species in the Cattle Only, Wildlife Only, and Combined Use areas, but its absolute cover never exceeded 15% on any site. In the Ungulate Exclosure, bluebunch wheatgrass was subordinate to Kentucky bluegrass and Canada bluegrass, which collectively provided about 15% cover on the site (Table 9).

In 1991, Idaho fescue contributed little to cover inside the Ungulate Exclosure, but it was relatively more prominent in each of the grazing treatment areas. Despite its cover never surpassing 10% in these areas, it was codominant in the Cattle Only and Wildlife Only areas, while it occurred as a minor subordinate in the Combined Use Area. Other key species, such as needle-and-thread, prairie junegrass, Richardson's needlegrass, and rough fescue, provided negligible cover in all areas (Table 9).

Total forb cover in 1991 varied from less than 10% in the Cattle Only Area to nearly 17% in the Ungulate Exclosure. Except for hairy golden-aster (*Chrysopsis villosa*), timber milk-vetch (*Astragalus miser*), and western yarrow in the Ungulate Exclosure, other forbs never exceeded 2% of canopy cover on any treatment area (Table 9).

Total tree and shrub cover was highest in the Combined Use Area and in the Ungulate Exclosure, where this group provided almost 20% cover. Bitterbrush was the dominant shrub on all treatment areas, ranging from less than 5% cover in the Cattle Only Area to more than 10% in the Ungulate Exclosure (Table 9).

By 2009, several floristic changes had occurred among the four treatment areas. Bluebunch wheatgrass, which was the dominant species in the Cattle Only, Wildlife Only, and Combined Use areas, declined in all treatment areas in 2009 (Tables 9 and 10).

TABLE 9 *Percent cover of selected plant species and soil substrates at the Skookumchuck Prairie Three-way Exclosure Site between 1991 and 2009*

Species	Ungulate Exclosure		Cattle Only		Wildlife Only		Combined Use	
Grasses	**1991**	**2009**	**1991**	**2009**	**1991**	**2009**	**1991**	**2009**
Bluebunch wheatgrass	4.6	0.9	11.7	3.8	12.6	5.1	9.7	2.4
Canada bluegrass	7.1	11.1	2.7	0.8	0.6	1.0	4.4	7.3
Idaho fescue	0.8	5.6	4.1	5.5	7.2	7.2	3.8	2.6
Kentucky bluegrass	9.5	7.8	1.8	4.7	1.6	1.5	2.8	1.6
Needle-and-thread	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Prairie junegrass	0.5	0.3	2.2	0.8	2.9	1.9	1.5	0.8
Richardson's needlegrass	0.0	2.1	1.4	1.8	1.1	3.6	1.9	10.4
Rough fescue	0.6	22.7	1.8	13.8	1.1	1.6	2.7	1.6
Total Grass Cover	**26.2**	**50.7**	**29.3**	**32.3**	**28.3**	**23.0**	**30.7**	**27.7**
Forbs								
Hairy golden aster	2.4	0.2	1.9	0.9	0.4	2.2	1.7	5.5
Timber milk vetch	5.7	0.0	1.1	0.0	4.7	0.2	2.2	0.0
Western yarrow	1.7	0.8	1.1	2.1	1.7	1.4	1.1	0.3
Total Forb Cover	**16.8**	**6.0**	**9.1**	**14.2**	**12.3**	**12.1**	**14.7**	**15.5**
Trees and Shrubs								
Bitterbrush	11.5	10.4	4.9	4.8	8.6	15.2	9.1	8.0
Ponderosa pine	0.0	0.0	2.4	4.9	1.6	2.1	4.0	5.0
Saskatoon	2.1	2.6	2.0	0.2	1.7	0.5	2.9	0.9
Total Tree and Shrub Cover	**18.4**	**15.2**	**14.8**	**16.2**	**12.7**	**19.2**	**18.2**	**16.3**
Substrates								
Litter	53.9	79.4	39.5	61.3	36.0	50.3	49.3	52.9
Soil	5.8	0.5	12.9	9.6	9.9	4.5	9.4	3.1

TABLE 10 *Repeated measures analysis of variance significance tests (P values) of key plant species and soil substrate cover by grazing treatment (Graze) and year (Year) at the Skookumchuck Three-way Exclosure Site*[a]

Effect	AGSP	FEID	FESC	STRI	AMAL	PUTR	LITT	SOIL
Graze	0.02	0.02	<0.01	0.05	0.38	0.08	0.03	<0.01
Year	<0.01	0.04	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Linear (L)	<0.01	0.14	<0.01	0.02	<0.01	0.25	0.09	<0.01
Graze × Year	0.19	<0.01	<0.01	0.25	0.06	0.09	0.24	<0.01
UE vs. CO × Year(L)	0.28	0.01	<0.01	0.20	0.03	0.74	0.93	0.23
UE vs. WO × Year(L)	0.30	<0.01	<0.01	0.34	0.35	0.08	0.43	0.38
UE vs. CU × Year(L)	0.60	<0.01	<0.01	0.68	<0.01	0.96	0.03	0.48
CO vs. WO × Year(L)	0.95	0.62	<0.01	0.73	0.23	0.04	0.49	0.74
CO vs. CU × Year(L)	0.57	0.06	<0.01	0.09	0.58	0.78	0.04	0.61
WO vs. CU × Year(L)	0.61	0.17	0.05	0.18	0.08	0.07	0.17	0.86

a AGSP = bluebunch wheatgrass; FEID = Idaho fescue; FESC = rough fescue; STRI = spreading needlegrass; AMAL = saskatoon; PUTR = bitterbrush; LITT = litter; UE = Ungulate Exclosure; CO = Cattle Only; WO = Wildlife Only; CU = Combined Use.

Rough fescue increased greatly in the Ungulate Exclosure and Cattle Only Area ($P<0.01$), becoming the dominant species on both sites, but it remained unchanged in the Wildlife Only and Combined Use areas (Tables 9 and 10). In 1991, most of the rough fescue plants found at the Skookumchuck Three-way Exclosure Site were in poor vigour (Ross and Wikeem, pers. obs. 1991). Plants growing inside the Ungulate Exclosure in 2009 were robust, while those in the Combined Use Area continued to lack vigour (Ross and Wikeem, pers. comm., 2009).

Idaho fescue also increased ($P<0.05$) inside the Ungulate Exclosure between 1991 and 2009, but it remained relatively unchanged in the other treatment areas (Tables 9 and 10). Although cover of this species in the Wildlife Only Area remained the same in 2009 as it was in 1991, it became the dominant species on the site because of the decline in bluebunch wheatgrass.

Richardson's needlegrass increased ($P<0.05$) in the Ungulate Exclosure, Wildlife Only Area, and Combined Use Area. The most pronounced change occurred in the Combined Use Area, where it replaced bluebunch wheatgrass as the dominant species, but increases in the other treatment areas were less striking (Tables 9 and 10).

Kentucky bluegrass and Canada bluegrass continued to be conspicuous in the Ungulate Exclosure in 2009, but their cover remained relatively unchanged between 1991 and 2009 in the Cattle Only and Wildlife Only areas. Kentucky bluegrass declined marginally in the Combined Use area, where it continued to be a minor species in the plant community (Table 9).

Similar to 1991, total forb cover ranged from about 6 to 17% among the treatment sites. Western yarrow increased slightly in the Cattle Only Area and declined marginally in the Combined Use Area (Table 9).

Tree and shrub cover varied between 15 and 20% among all grazing treatment areas in 2009. Bitterbrush continued to be the dominant shrub on all areas in 2009, but its cover changed ($P<0.10$) only in the Wildlife Only Area (Tables 9 and 10).

Litter cover increased ($P<0.05$) between 1991 and 2009 on all the treatment areas except the Combined Use Area (Tables 9 and 10). Litter cover changed the most in the Ungulate Exclosure and least in the Wildlife Only Area. There was more than 30% more litter in the Ungulate Exclosure compared to the Combined Use Area by 2009. Exposed mineral soil decreased ($P<0.01$; Table 10) on all treatment sites except the Cattle Only Area between 1991 and 2009. The greatest change occurred inside the Ungulate Exclosure, where exposed mineral soil was reduced to less than 1% cover (Table 9).

4.5.2 Plant species response over time Although there were numerous changes in cover among individual plant species between 1991 and 2009, not all species responded in the same way, presumably due to the different grazing treatments (Table 9).

In 1991, bluebunch wheatgrass cover varied from approximately 5% in the Ungulate Exclosure to nearly 13% in the Wildlife Only Area (Table 9), but, by 2009, its cover had declined on all sites (Tables 9 and 10; Figure 7). These declines likely resulted from a combination of ungulate grazing, plant competition, and annual weather patterns. Idaho fescue ($P<0.05$), Richardson's needlegrass ($P<0.10$), and rough fescue ($P<0.01$) all increased in the Ungulate Exclosure (Table 9), which probably contributed to bluebunch wheatgrass decline.

In 1991, rough fescue provided less than 3% canopy cover on all the treatment areas. By 2009, it was the dominant species in both the Ungulate Exclosure and the Cattle Only Area (Table 9). In contrast, cover of this species was virtually unaltered in the Wildlife Only and Combined Use areas over the same time period (Table 9; Figure 8). The prominence of rough fescue in the Ungulate Exclosure and Cattle Only Area likely resulted from reduced grazing pressure, especially in the Ungulate Exclosure, where its cover was nearly double that in the Cattle Only Area ($P<0.01$) (Tables 9 and 10; Figure 8).

Idaho fescue ranged from less than 1% cover at the Ungulate Exclosure to about 7% in the Wildlife Only Area in 1991. In 2009, Idaho fescue cover was highest in the Wildlife Only Area and lowest in the Combined Use Area (Table 9). Cover significantly increased ($P<0.05$) inside the Ungulate Exclosure between 1991 and 2009, but no significant trends were observed on the other treatment areas (Table 9; Figure 9). A significant linear grazing × year interaction indicated that the increasing trend in Idaho fescue cover between the Combined Use Area and the Ungulate Exclosure between 1991 and 2009 was steeper in the exclosure than in the grazed area (Tables 9 and 10; Figure 9).

Richardson's needlegrass was found on all grazing treatment areas and increased on all areas except the Cattle Only Area between 1991 and 2009 (Tables 9 and 10). Generally, changes were modest, with cover never extending beyond 5% except in the Combined Use Area, where it advanced from less than 2% to more than 10% between 1991 and 2009 (Table 9). Other minor changes in cover were also found for Kentucky bluegrass (Table 9) and Sandberg's bluegrass.

Trees and shrubs are an important part of the plant communities on all grazing treatment areas. Combined tree and shrub cover varied from 13–18% in 1991 to 15–20% in 2009 (Table 9). Except for the Wildlife Only Area, where cover increased from about 13–20%, tree and shrub cover remained relatively constant in all treatment areas over the study period.

Diet studies at Skookumchuck Prairie from 1992 to 1994 revealed that saskatoon provided important browse for deer, elk, and cattle (Ross 1997). Saskatoon cover rarely exceeded 2% among grazing treatments between 1991 and 2009 (Table 9). Despite its low cover, significant linear grazing × year interactions indicated that saskatoon declined marginally between 1991 and 2009 in the Combined Use ($P<0.01$) and Cattle Only areas ($P<0.05$) compared to the Ungulate Exclosure (Table 10; Figure 10).

Although bitterbrush was the dominant shrub in all grazing treatment areas (Table 9), and was eaten by cattle, deer, and elk at various times of the year (Ross 1997), its cover remained constant in the Ungulate Exclosure, Cattle Only, and Combined Use areas between 1991 and 2009 (Table 9). In contrast, a significant linear grazing × year interaction ($P<0.05$) indicated that between 1991 and 2009, its cover nearly doubled at the Wildlife Only Area compared to the Cattle Only Area, where it remained virtually changed (Tables 9 and 10).

After 18 years, litter cover was highest in the Ungulate Exclosure compared to the other three grazing treatment sites (Table 9). Significant linear grazing × year interactions ($P<0.05$), however, indicated that litter increased in the Ungulate Exclosure and the Cattle Only areas, while the trend in litter cover remained essentially unchanged in the Wildlife Only and Combined Use areas (Table 10; Figure 11).

Exposed mineral soil cover was generally lower on all sites in 2009 compared to 1991 (Tables 9 and 10). The lack of significant linear grazing × year interactions, however, indicated that these downward trends were similar among all grazing treatments (Table 10; Figure 12).

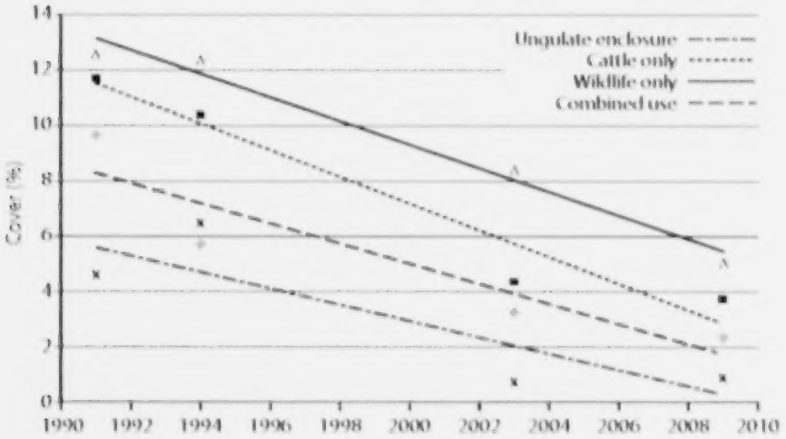

FIGURE 7 *Cover of bluebunch wheatgrass at the Skookumchuck Three-way Exclosure Site between 1991 and 2009 for grazing treatments.*

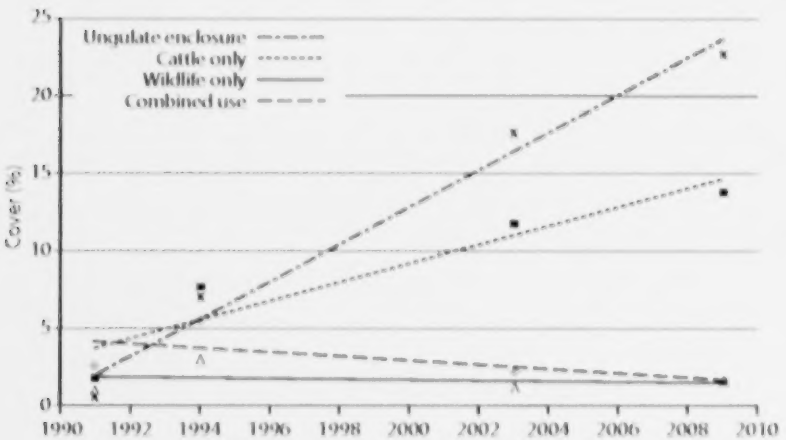

FIGURE 8 *Cover of rough fescue at the Skookumchuck Three-way Exclosure Site between 1991 and 2009 for grazing treatments.*

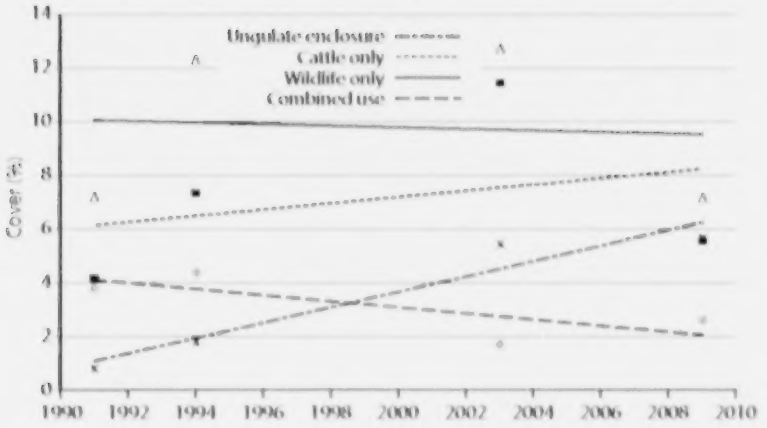

FIGURE 9 *Cover of Idaho fescue at the Skookumchuck Three-way Exclosure Site between 1991 and 2009 for grazing treatments.*

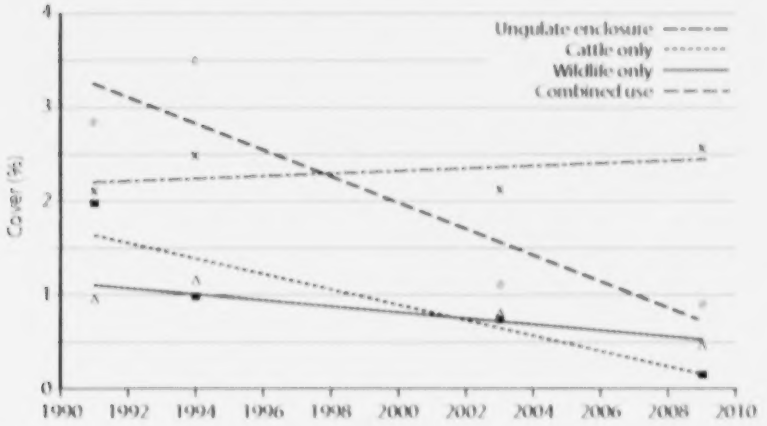

FIGURE 10 *Cover of saskatoon at the Skookumchuck Three-way Exclosure Site between 1991 and 2009 for grazing treatments.*

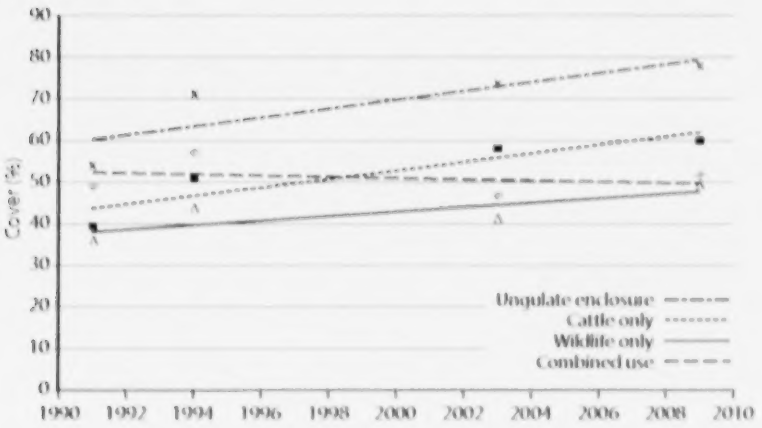

FIGURE 11 *Cover of litter at the Skookumchuck Three-way Exclosure Site between 1991 and 2009 for grazing treatments.*

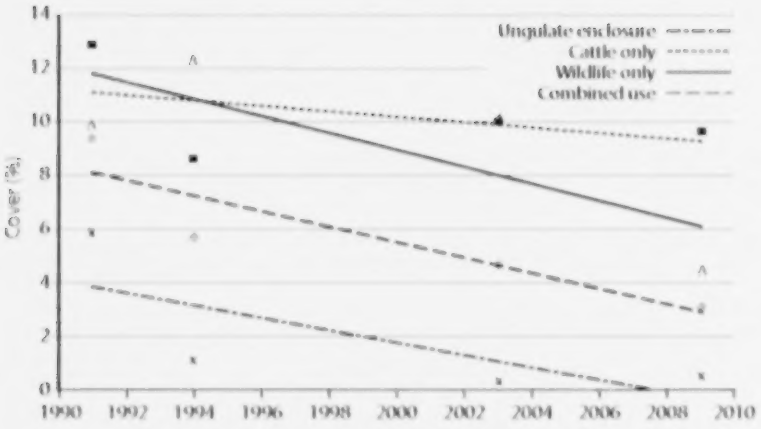

FIGURE 12 *Cover of exposed mineral soil at the Skookumchuck Three-way Exclosure Site between 1991 and 2009 for grazing treatments.*

5 DISCUSSION

Long term exclosures provide a rare opportunity to evaluate the status of, and change in, relatively undisturbed plant communities over extended time periods. Such information affords insight into plant ecological processes and possible end points in succession, which are valuable for assessing the effects of grazing management and other disturbance regimes. An understanding of late seral steady states provides an important benchmark for evaluating the progress and the position of intermediate seral plant communities. The rate of recovery provides a framework for management to gauge reasonable time frames for plant community change and evaluate the composition and productivity of various seral stages to supply resource values.

The classification of plant communities and the role of individual key species for wildlife and cattle have not been clearly elucidated for the Rocky Mountain Trench. At the onset of this study, we assigned the Skookumchuck Prairie sites to the Ponderosa Pine Kootenay Dry Hot Variant, and the Premier Ridge and Pickering Hills sites to the Interior Douglas fir Kootenay Dry Mild Variant (Braumandl and Curran 1992; Ross 1997). Site descriptions for climax plant communities for each of these variants, however, did not include several species that were found on all sites with important wildlife and range management values, such as rough fescue, Idaho fescue, and bitterbrush (Braumandl and Curran 1992).

Plant communities containing Idaho fescue, rough fescue and bluebunch wheatgrass have been described on open grassland in Washington (Daubenmire 1992), Idaho (Steele et al. 1981), and Montana (Pfister et al. 1977); and in southern Alberta (Willms et al. 1985), Saskatchewan (Coupland 1992), and British Columbia (McLean 1970). These species also exist as sympatric dominants or codominants in ponderosa pine and open Douglas fir forests in Montana (Pfister et al. 1977; Gruell et al. 1982), southern Idaho (Steele et al. 1981), and British Columbia (Brayshaw 1970; McLean 1970).

In British Columbia, rough fescue, Idaho fescue, and bluebunch wheatgrass form late seral communities on open grassland, or are important understorey species in the Similkameen, Kettle, and Okanagan Valleys (Brayshaw 1970; McLean 1970; Lloyd et al. 1990), and in the southern part of the Rocky Mountain Trench (McLean and Holland 1958; Wikeem and Wikeem 2007). The specific species mix and dominance of these species in the ponderosa pine and Douglas-fir zones in British Columbia are usually rationalized as variations along gradients of topography, soils, moisture, and temperature, with bluebunch wheatgrass usually occupying the relatively low-elevation drier habitats, whereas the fescues are most abundant at higher elevations on moist upland sites (McLean 1970). McLean and Marchand (1968) contended that Idaho fescue often replaces rough fescue in late seral communities in the southern part of the Trench.

5.1 Skookumchuck Prairie Historical Exclosure Site

Plant community succession has advanced slowly at the Skookumchuck Prairie Historical Exclosure Site since it was constructed in 1951. Initially, both the grazed and ungrazed (exclosure) areas were dominated by Sandberg's bluegrass and low pussytoes, and were considered to be in "poor range condition" (McLean and Tisdale 1972). In 1960, very little had changed on either area since the exclosure was constructed, but after 19 years of protection (1970), the ungrazed vegetation had progressed to "excellent range condition" (McLean and Tisdale 1972), presumably based on the codominance of bluebunch wheatgrass and rough fescue, which together comprised 75% cover (Table 5). Additional sampling in 1982, however, indicated that the plant community had not reached a steady state in 1970 as first thought. Bluebunch wheatgrass, which dominated the site in 1970, had declined dramatically and was replaced by rough fescue as the dominant species (Table 5; McLean and Wikeem 1986).

Over the next 39 years, the vegetation inside the exclosure at the Skookumchuck Prairie Historical Exclosure Site progressed further (Table 11). By 1994, Ross and Wikeem (2002) reported that rough fescue and Idaho fescue had largely replaced bluebunch wheatgrass, and, by 2009, bluebunch wheatgrass cover was reduced to less than 5% (Table 5). In contrast, rough fescue reached its maximum cover of nearly 60% in 1982 and then declined to less than 25% by 2009. Idaho fescue, which first appeared on the site in 1982, increased over the next 27 years and has been a codominant with rough fescue since 1991 (Table 5).

Other than ponderosa pine, shrubs and trees were a minor component of the flora inside the exclosure, even after 58 years of protection from grazing. In fact, up to 1970, bearberry was the only shrub to immigrate into the exclosure, but it disappeared from the site by 1982 (Ross and Wikeem 2002). Recruitment of ponderosa pine seedlings occurred slowly inside the exclosure and provided <3% cover 40 years after the exclosure was built. By 2009, ponderosa pine cover had more than quadrupled from 1991 (Table 5). Higher than normal precipitation in 9 of the 18 years between 1992 and 2009 (Table 1) likely contributed to the establishment and survival of ponderosa pine, although increased litter cover provides slightly more mesic conditions for seeds to germinate and establish. Additionally, ponderosa pine and fescue litter are characterized by low bulk density and low relative volume (Bai et al. 2000). Therefore, seeds are not likely trapped in their loose structure but fall through, contacting mineral soil.

5.2 Premier Ridge and Pickering Hills

Vegetation changes in the grazed areas at Premier Ridge and Pickering Hills have essentially been stagnant for 18 years, indicating that combined cattle and wildlife grazing pressure on the sites has been impeding recovery. Inside the exclosures, there has been little advancement from early seral conditions, and specific changes in the flora were different between the two sites.

TABLE 11 *Plant associations found inside the Skookumchuck Prairie Historical Exclosure Site between 1951 and 2009*

Year sampled	Interval (years)	Plant association
1951	0	Sandberg's bluegrass/low pussytoes/prairie junegrass [a]
1960	9	Bluebunch wheatgrass/prairie junegrass/Sandberg's bluegrass [a]
1970	19	Bluebunch wheatgrass/rough fescue/spiny phlox [a]
1982	31	Rough fescue/bluebunch wheatgrass/spiny phlox [a, b]
1991	40	Ponderosa pine/rough fescue/Idaho fescue/bluebunch wheatgrass [c]
1994	43	Ponderosa pine/rough fescue/Idaho fescue/bluebunch wheatgrass [d]
2009	58	Ponderosa pine/rough fescue/Idaho fescue/spiny phlox [d]

a Ponderosa pine absent.
b Idaho fescue first present.
c Ponderosa pine first present.
d Ponderosa pine present but not dominant cover on site.

At Premier Ridge, neither rough fescue nor Idaho fescue were encountered on the transects, but several vigorous rough fescue plants were found inside the exclosure (Wikeem and Ross, pers. obs., 2009), suggesting that ecological potential for recovery exists on the site. The slow rate of recovery inside the exclosure could be partly explained by the secondary disturbance caused by two fires in 2001 and 2008 that burned through the exclosure and consumed most of the vegetation. Litter accumulation on the site could have produced a hot fire that affected both rough fescue and Idaho fescue, which are adversely affected by intense fires (Conrad and Poulton 1966; Antos et al. 1983).

Similar to Premier Ridge, the Pickering Hills sites appear to have some ecological capacity for recovery, but vegetation change has been very slow. Between 1991 and 2009, rough fescue and Idaho fescue were found inside the exclosure and in the grazed area, respectively, but the cover of both species was very low. Their presence on the site, however, provides a nucleus for recovery that was not apparent in 1991, but short-term advancement to later seral stages appears unattainable.

Based on the well developed shrub layer inside the exclosure, Pickering Hills appears to be a different site from those sampled at Skookumchuck Prairie, and is possibly different from Premier Ridge as well. On forested sites such as Premier Ridge and Pickering Hills, the optimum forage conditions for livestock and wildlife likely do not occur in late seral communities where the forest canopy is closed. This illustrates the need for proper site classification to predict successional sequences and adapt management for seral stages that provide the optimum mix of plant species to achieve specific objectives. Intermediate seral stages, which provide a combination of overstorey for escape and thermal cover, and produce forage for wildlife and livestock, may be an appropriate management objective on these sites.

5.3 Skookumchuck Prairie Three-way Exclosure Site

Early seral plant communities dominated all four areas at the Three-way Exclosure Site in 1991. Although alterations to the mix of ungulates, and the timing and intensity of grazing, produced different effects on plant communities in the three-way exclosure system between 1991 and 2009, little change was apparent in any of the grazing treatment areas until 2003 (Rosentreter 2006).

Grazing effects in the plant communities were approximately proportional to reductions in combined grazing pressure from cattle, elk, and deer, with the Ungulate Exclosure showing the greatest increases in rough fescue, Idaho fescue, and litter cover (Table 9). The improvement in rough fescue cover in the Cattle Only Area was likely associated with the shorter duration and reduced grazing intensity that occurred on the site after it was fenced to exclude elk and deer in 1991. Before fencing, the site was almost continuously grazed by elk, deer, and cattle compared to 1 month of cattle grazing alone between June and September after the study began (Ross 1997; Appendix 2).

Similar to Skookumchuck Prairie Historical Exclosure Site, there was little change in the plant communities in the Ungulate Exclosure or Cattle Only Area over the first 4 years of the study (Ross 1997), and none of the changes were apparent until the site was re-sampled in 2003 (Rosentreter 2006). This lag time in the response of rough fescue and Idaho fescue is in agreement with previous research in similar environments (McLean and Tisdale 1972; Anderson and Holte 1981; Willms et al. 1985), and likely results from individual plants requiring sufficient time to re-establish damaged root systems before they produced larger volumes of above-ground biomass or before new plants are recruited onto the site.

Unlike the fescues, bluebunch wheatgrass declined in all four areas over 18 years but likely for different reasons in each area. Whereas the decline in bluebunch wheatgrass in the Ungulate Exclosure probably resulted from competition, its decline in the Cattle Only Area could be attributed to the timing of grazing, plant competition, or both. Data collected from the site between 1992 and 1995 indicated that bluebunch wheatgrass comprised 12–17% of cattle diets during their period of use on the area (Ross 1997). Bluebunch wheatgrass is most vulnerable to defoliation during the boot to early flowering stage (Mueggler 1975; McLean and Wikeem 1986), particularly if plants are repeatedly overused for 3 or more consecutive years (Wilson et al. 1966).

Competition with rough fescue and Idaho fescue could also have contributed to the decline in bluebunch wheatgrass inside the Ungulate Exclosure and in the Cattle Only Area. In a clipping study, Mueggler (1972) found that bluebunch wheatgrass growth was adversely affected by competition from Idaho fescue whether bluebunch wheatgrass plants were clipped or not.

After 18 years of grazing, the cover of rough fescue and Idaho fescue remained virtually unchanged in the Wildlife Only and Combined Use areas, while bluebunch wheatgrass declined on both sites (Table 9). At the same time, rough fescue increased greatly within the Ungulate Exclosure and to a lesser extent in the Cattle Only Area. These responses imply that grazing pressure was the primary factor regulating key bunchgrass populations, and that current grazing in both areas exceeds the level for individual plants or plant communities to initiate recovery. Even though grazing pressure in the Wildlife Only Area was reduced with the removal of cattle during the study, this site remained in a steady state from wildlife grazing alone.

Cattle grazed the Combined Use Area between June and September for approximately 1 month annually (Table 3; Appendix 2), while elk, mule deer, and white-tailed deer used the area in all seasons between 1992 and 1994 (Ross 1997). This combined use indicates year-long grazing, although grazing intensity likely varied as most elk and deer dispersed from the winter range during summer (Jamieson and Hebert 1993). The highest grazing pressure, however, likely occurred between spring green-up and early summer when all four ungulate species sequentially or collectively used the site, and during the period where bluebunch wheatgrass is most susceptible to defoliation (McLean and Wikeem 1986).

5.4 Recovery Rate

Based on the results of the Skookumchuck Prairie Historical Exclosure Site and data from other sites in British Columbia, McLean and Tisdale (1972) estimated that recovery to "excellent range condition" of fully rested overgrazed ranges required 20–40 years in the rough fescue and ponderosa pine zones, with little change taking place in the first decade. After re-sampling the site in 1982, McLean and Wikeem (1986) suggested that some sites could take up to 50 years to fully recover. Results from this study suggest that even after nearly 60 years of protection, additional changes might be expected, although the plant community appears to have reached a tenuous steady state since about 1991 (Table 5; Table 11).

The rate of recovery and specific outcome regarding the species composition following complete rest from grazing can be influenced by several factors. Recruitment of new plants into the community could arise from seed in the soil seed bank or from seed production on residual plants; however, rough fescue, bluebunch wheatgrass, and Idaho fescue all intermittently produce seeds that are often non-viable (Stout et al. 1981; Quinton et al. 1982; Goodwin et al. 1995). Recovery of the key bunchgrasses is more likely from residual root stock rather than from seed, with the rate of succession related to the number of rough fescue or bluebunch wheatgrass plants present at the time of fencing (Willms et al. 1985). In addition, the rate of recovery under these circumstances depends on the distribution of the remaining individual plants and the vigour of each plant when grazing pressure is reduced or eliminated.

Bluebunch wheatgrass, rough fescue, and Idaho fescue have demonstrated variable patterns of decline and recovery from grazing throughout their sympatric range. For plains rough fescue (*Festuca hallii*), Johnston and MacDonald (1967) suggested that recovery from overgrazing can be slow because of the plant's limited ability to produce lateral tillers from axillary meristems. Moreover, the rate of recovery appears to advance more quickly once plants are released from grazing pressure and they develop deeper root systems (McLean and Wikeem 1986).

Less is known about Idaho fescue and bluebunch wheatgrass recovery rates under field conditions. Mueggler (1975) estimated from clipping trials that recovery from a state of low vigour could require 6–8 years of protection for these two species, respectively. The results of this study, however, suggest that this estimate is low under field conditions in the Rocky Mountain Trench.

Climate cycles and seasonal weather patterns are important in determining the rate of plant succession at Skookumchuck Prairie. Between 1990 and 2009, precipitation during the growing season averaged 107% of normal,

cresting at 175% of normal in 2005, with other wet years occurring in 1993, 1995, 1998, and 2004 (Table 1). Total grass cover peaked in 1994 (Table 5), likely in response to the above-normal precipitation in April, May, and June, which followed the second wettest year during the study (Table 1). April and May 1994 were also 122.7% and 110.7% warmer than normal, respectively. The effects of above-normal growing-season precipitation and temperature, combined with no grazing, likely allowed plants to produce foliage, photosynthesize, translocate carbohydrates to the roots, and extend root systems deeper into the soil profile.

6 CONCLUSIONS

Anderson and Holte (1981) suggested that a general pattern of recovery on many range sites involves "slow change during the first decade or so of rest followed by more rapid re-vegetation as previously depleted populations build up their size and seed production." The actual time for improvements to be detected, however, depends on the aridity of the site and the initial conditions on the site before recovery begins.

Evaluation of plant species response to grazing on East Kootenay ranges can be challenging. Results from this study indicate that Idaho fescue, rough fescue, and saskatoon decreased with mixed ungulate grazing on the sites sampled, while bluebunch wheatgrass, needle-and-thread, Richardson's needlegrass, and bitterbrush increased. Although the key bunchgrasses have a capacity to recover given proper management and sufficient time, the formation of identical late seral communities on all the sites, or the prospect of any site recovering to its former pristine steady state seems unlikely.

The relative position of plant communities at any point in time needs to be evaluated against the current and long-term site-specific goals and objectives to produce particular social values. These may range from products that require pristine conditions to others that are best suited to earlier seral stages. On wildlife winter ranges in the East Kootenay, and particularly on those sites where forest canopies may close, intermediate stages of succession may be more valuable for wildlife and cattle management than late seral stages. Under such circumstances, key species such as rough fescue, bluebunch wheatgrass, Idaho fescue, saskatoon, buckbrush, and bitterbrush are more abundant and productive than on sites where forest canopies have closed.

While much can be done with improved livestock and wildlife management, external management inputs may be necessary to achieve desired plant communities. Fire, chemical treatments, or mechanical treatments may be required to shift bitterbrush-dominated communities to a seral stage containing less bitterbrush and more desirable shrubs such as saskatoon, low Oregon-grape (*Berberis repens*), and buckbrush.

The most important objective for the sustainability of integrated resources is land management, and in particular, management of soils, herbaceous forage species, and browse. Instead of independent management of individual ungulates, landscape units should be managed holistically with livestock and wildlife considered as components of the system.

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APPENDIX 1 Common and scientific names of vascular plant species

Common Name[a]	Scientific Name
Grasses/Grasslike	
Bluebunch wheatgrass	*Agropyron spicatum*
Canada bluegrass	*Poa compressa*
Cheatgrass	*Bromus tectorum*
Columbia needlegrass	*Stipa columbiana*
Idaho fescue	*Festuca idahoensis*
Kentucky bluegrass	*Poa pratensis*
Needle-and-thread	*Stipa comata*
Northwest sedge	*Carex concinnoides*
Pinegrass	*Calamagrostis rubescens*
Prairie junegrass	*Koeleria cristata*
Richardson's needlegrass	*Stipa richardsonii*
Rough fescue	*Festuca scabrella*
Sandberg's bluegrass	*Poa sandbergii*
Sedge species	*Carex* spp.
Slender wheatgrass	*Agropyron trachycaulum*
Smooth brome	*Bromus inermis*
Thickspike wheatgrass	*Agropyron dasystachyum*
Timothy	*Phleum pratense*
Western needlegrass	*Stipa occidentalis*
Western wheatgrass	*Agropyron smithii*
Forbs	
Alfalfa	*Medicago sativa*
American vetch	*Vicia americana*
Baker's mariposa lily	*Calochortus apiculatus*
Balsamroot	*Balsamorhiza sagittata*
Bird's-foot trefoil	*Lotus corniculatus*
Bitterroot	*Lewisii rediviva*
Black medic	*Medicago lupulina*
Brown-eyed Susan	*Gaillardia aristata*
Canada goldenrod	*Solidago canadensis*
Chickweed	*Cerastium arvense*
Cinquefoil species	*Potentilla* spp.
Common harebell	*Campanula rotundifolia*
Common mullein	*Verbascum thapsus*
Compound fleabane	*Erigeron compositus*
Dandelion	*Taraxacum officinale*
Death camas	*Zigadenus venenosus*
Desert parsley	*Lomatium macrocarpum*
Douglas' silene	*Silene douglasii*
Dune goldenrod	*Solidago spathulata*
Early blue violet	*Viola adunca*
Fairy candelabra	*Androsace septentrionalis*
Field filago	*Filago arvensis*
Field locoweed	*Oxytropis campestris*
Hairy golden aster	*Chrysopsis villosa*
Hawkweed species	*Hieracium* spp.

APPENDIX 1 (Continued)

Common Name[a]	Scientific Name
Hoelboel's rockcress	*Arabis holboellii*
Leafy aster	*Aster foliaceous*
Long leafed daisy	*Erigeron corymbosus*
Low pussytoes	*Antennaria dimorpha*
Mariposa lily	*Calochortus macrocarpus*
Meadow aster	*Aster campestris*
Narrow leaved blue eyed grass	*Sisyrinchium angustifolium*
Narrow leaved goosefoot	*Chenopodium leptophyllum*
Nine leaved lomatium	*Lomatium triternatum*
Nodding onion	*Allium cernuum*
Nuttal's pussytoes	*Antennaria parviflora*
Old man's beard	*Geum triflorum*
Pacific anemone	*Anemone multifida*
Prairie crocus	*Anemone patens*
Prairie groundsel	*Senecio canus*
Prairie peppergrass	*Lepidium densiflorum*
Pretty shootingstar	*Dodecatheon pauciflorum*
Prickly lettuce	*Lactuca serriola*
Purple owl clover	*Orthocarpus tenuifolia*
Rosy pussytoes	*Antennaria microphylla*
Round leaved alumroot	*Heuchera cylindrica*
Scouler's hawkweed	*Hieracium scouleri*
Shaggy fleabane	*Erigeron pumilus*
Showy aster	*Aster conspicuus*
Showy daisy	*Erigeron speciosus*
Slender hawksbeard	*Crepis atribarba*
Small flowered penstemon	*Penstemon procerus*
Smooth agoseris	*Agoseris glauca*
Spiny phlox	*Phlox rigida*
Spotted knapweed	*Centaurea maculosa*
Spreading dogbane	*Apocynum androsaemifolium*
Stickseed	*Lappula echinata*
Stoneseed	*Lithospermum ruderale*
Sulphur buckwheat	*Eriogonum umbellatum*
Sulphur cinquefoil	*Potentilla recta*
Sulphur paintbrush	*Castilleja sulphurea*
Thompson's paintbrush	*Castilleja thompsonii*
Thread leaved fleabane	*Erigeron filifolius*
Timber milk vetch	*Astragalus miser*
Tiny penstemon	*Penstemon confertus*
Western yarrow	*Achillea millefolium*
White clover	*Trifolium repens*
White sweet clover	*Melilotus alba*
Wild strawberry	*Fragaria virginiana*
Wyeth's buckwheat	*Eriogonum heracleoides*
Yellow buckwheat	*Eriogonum flavum*
Yellow owl clover	*Orthocarpus luteus*
Yellow salsify	*Tragopogon dubius*

APPENDIX 1 (Concluded)

Common Name[a]	Scientific Name
Trees and Shrubs	
Bearberry	*Arctostaphylos uva-ursi*
Birch-leaved spirea	*Spiraea betulifolia*
Bitterbrush	*Purshia tridentata*
Buckbrush	*Ceanothus velutinus*
Chokecherry	*Prunus virginiana*
Douglas fir	*Pseudotsuga menziesii*
Lodgepole pine	*Pinus contorta*
Low Oregon grape	*Berberis repens*
Mock orange	*Philedelphus lewisii*
Pasture sage	*Artemisia frigida*
Ponderosa pine	*Pinus ponderosa*
Prickly rose	*Rosa acicularis*
Rose species	*Rosa* spp.
Saskatoon	*Amelanchier alnifolia*
Snowberry	*Symphoricarpos albus*
Soopolallie	*Shepherdia canadensis*
Trembling aspen	*Populus tremuloides*
Wood's rose	*Rosa woodsii*

[a] Plant list includes species found on the study sites, and listed in text and tables. Vascular plant nomenclature follows Hitchcock and Cronquist 1973.

APPENDIX 2 Cattle stocking (animal unit months [AUMs]) and rotations at Skookumchuck Prairie, Pickering Hills, and Premier Ridge between 1992 and 2009

Location/Site	1992		1993		1994		1995		1996		1997	
	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates
Skookumchuck Prairie												
Three-way Exclosure Cattle Only Area	38	June 15–July 15	38	Sept. 1–Sept. 30	43	July 10–Aug. 10	0	No use	0	No use	40	May 10–June 28
Three-way Exclosure Combined Use Area	48	June 15–July 15	38	Sept. 1–Sept. 30	72	July 10–Aug. 10	99	Oct. 1–Oct. 15	0	No use	200	May 29–July 6
Historical Exclosure Grazed Area	0	No use		Not available		Not available		Not available	194	May 7–June 15		Not available
Premier Ridge	104	May 1–June 15	60	Aug. 1–Aug. 30	91	May 15–June 19	0	No use		Not available		Not available
Pickering Hills	199	Aug. 11–Sept. 4	270	July 10–Aug. 10	270	July 25–Aug. 25	270	Sept. 4–Sept. 23	114	Sept. 24–Oct. 15	285	Aug. 6–Sept. 6

Location/Site	1998		1999		2000		2001		2002		2003	
	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates
Skookumchuck Prairie												
Three-way Exclosure Cattle Only Area		Not available		Not available		Not available	0	No use	39	May 27–May 31	27	May 22–Juyl 5
Three-way Exclosure Combined Use Area	255	Sept. 1–Oct. 15		Not available		Not available	0	No use	79	May 17–May 26	108	May 30–June 11
Historical Exclosure Grazed Area		Not available		Not available		No use		No use	87	May 6–May 16	125	May 15–May 29
Premier Ridge		Not available	0	No use	50	Sept. 5–Sept. 18	50	Sept. 1–Sept. 14	92	Sept. 1–Sept. 28	107	Aug. 23–Sept. 22
Pickering Hills	290	Aug. 4–Aug. 29	293	Sept. 20–Oct. 10	350	July 3–Aug. 7	96	July 15–Aug. 1	239	Aug. 10–Sept. 6	216	July 10–Aug. 2

Location/Site	2004		2005		2006		2007		2008		2009	
	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates	AUM	Dates
Skookumchuck Prairie												
Three-way Exclosure Cattle Only Area	71	May 19–Sept. 30	63	May 6–Aug. 1	31	May 12–July 1	59	May 12–May 20	60	May 20–May 30	11	May 15–June 7
Three-way Exclosure Combined Use Area	103	June 5–June 15	107	June 18–July 2	94	June 19–July 1	0	No use	72	May 31–June 12	77	June 8–July 7
Historical Exclosure Grazed Area	121	May 23–June 4	100	June 4–June 17	115	June 3–June 18	0	No use	72	June 13–June 24	121	July 8–July 23
Premier Ridge	73	July 25–Aug. 17	92	Aug. 21–Sept. 15	72	July 15–Aug. 5	0	No use	60	June 25–July 10	0	No use
Pickering Hills	320	July 11–July 31	299	July 21–Aug. 12	259	July 22–Aug. 15	0	No use	177	July 29–Aug. 11	177	July 11–Aug. 2